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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WASHINGTON 25, D. C.

December 13, 1956

AEC - 260/7

Mr. Robert D. Nininger
Assistant Director for Exploration
Division of Raw Materials
U. S. Atomic Energy Commission
Washington 25, D. C.

Dear Bob:

Transmitted herewith are three copies of TEI-598, "Some uranium deposits in Arizona," by H. C. Granger and R. B. Raup, June 1956.

Sincerely yours,

John H. Eric
for W. H. Bradley
Chief Geologist

JAN 24 2001

[redacted]

Geology and Mineralogy

This document consists of 85 pages.
Series A

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

SOME URANIUM DEPOSITS IN ARIZONA*

By

H. C. Granger and R. B. Raup

June 1956

Trace Elements Investigations Report 598

This preliminary report is distributed without editorial and technical review for conformity with official standards and nomenclature. It is not for public inspection or quotation.

*This report concerns work done on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

[redacted]

USGS - TEI-598

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SOME URANIUM DEPOSITS IN ARIZONA

By H. C. Granger and R. B. Raup

ABSTRACT

Between 1950 and 1954 the writers sought and examined deposits of uranium-bearing minerals in Arizona. This report describes most of the localities examined where anomalous radioactivity was detected.

Five of the localities described are of particular interest because of their potential as uranium producers or because of their unusual occurrence. The deposit on the Orphan claim in Coconino County occurs in a slump block of Coconino sandstone and contains material equivalent in radioactivity to as much as 12.5 percent uranium. The deposit exposed in Hack's mine in Mohave County is in a somewhat similar slump block. The deposits in the Dripping Spring quartzite in Gila County are unusual inasmuch as they apparently are genetically related to diabase. A considerable quantity of uraninite-bearing ore has been produced from several of the many deposits in siltstone and hornfelsized siltstone units of the Dripping Spring. The potential of the Annie Laurie deposit in Santa Cruz County has never been properly evaluated because of doubtful interpretations of the geology. Inasmuch as the uranium occurs adjacent to a north-trending fault zone that dips east, exploratory drilling should be east rather than west of the fault zone. The source of the uranium minerals found on the dumps of the Abe Lincoln mine in Yavapai County is unknown because access to the mine workings is prohibited by the presence of caved rock and water. Specimens of ore-grade uranium on the dumps may indicate the presence of small but rich pockets of ore in the mine.

The deposits in the Dripping Spring quartzite have received further study by the writers and the deposit on the Orphan claim has been further explored. It is suggested, however, that a coordinated study of the Orphan and Hack's deposits might be profitable and that the Annie Laurie and Abe Lincoln deposits might be worthy of continued study and development.

INTRODUCTION

The occurrence of uranium minerals in Arizona became of increased interest after World War II because of the immediate need for fissionable materials. Accordingly, personnel of the U. S. Geological Survey examined known and reported occurrences of uranium in Arizona and searched for new deposits on the basis of geologic evidence. This report describes the more notable uranium deposits examined by the writers between 1950 and 1954, and includes many data not heretofore reported.

The senior author examined reported occurrences of uranium in Arizona during parts of 1950 and 1951. He was accompanied by E. P. Kaiser and J. W. Adams for some of the work. The junior author, with D. V. Haines, sought new occurrences of uranium in Arizona from the latter part of 1952 until March 1954. The area in which the junior author worked did not include Coconino, Apache, and Navajo Counties, nor the northern half of Mohave County. More recent studies of several of the deposits discussed have been conducted by other geologists. Except for brief sample data, none of this later work by other geologists is included in this report. Publications of these workers are, however, referred to in the text. The writers' work was done on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

Uranium minerals occur in a wide variety of settings in Arizona. Deposits in sandstone are common in the northern part of the state, but all are not typical of the "Plateau type." Two aberrant types are at Hack's mine and on the Orphan claim described herein. Vein-like deposits in siltstone are abundant in Gila County near the center of the state. Other vein-type deposits occur in many diverse rock types throughout the southern half of the state. More nondescript disseminated types of deposits occur in Mohave, Pima, Graham, and Gila Counties. The mineralogy of the deposits is equally diverse; for example, carnotite, metatorbernite, kasolite, pyromorphite, or uraninite is the principal uranium-bearing mineral at one or more of the deposits described in this report. In addition, such rarer minerals as bassetite, schoepite, dumontite, and uranocircite have been identified.

Figure 1 shows the locations of all deposits described in this report. In the text, descriptions of the geology and mineralogy of the individual deposits are arranged alphabetically according to the counties in which they occur.

The writers wish to express appreciation to E. D. Wilson and J. W. Anthony of the Arizona Bureau of Mines and to Steven Malloy, LaMar Evans, and others at the Southwest Experimental Station of the U. S. Bureau of Mines for their many helpful suggestions and courtesy extended during these reconnaissances. R. J. Wright of the U. S. Atomic Energy Commission conducted the senior author to several of the uranium deposits described in this text and supplied unpublished information. Especially helpful were the many miners and prospectors of Arizona.

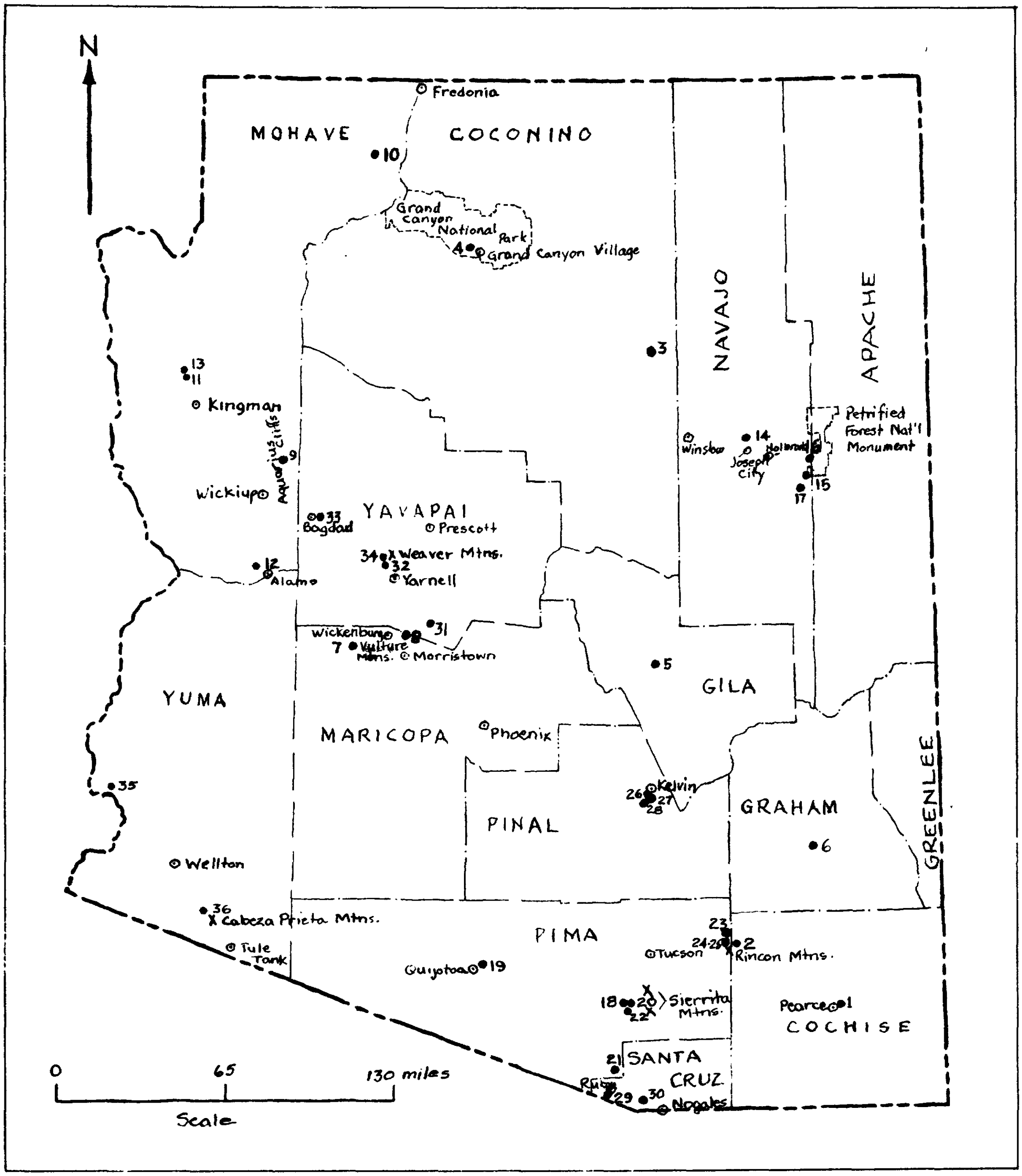

FIGURE 1.—INDEX MAP OF ARIZONA, SHOWING URANIUM DEPOSITS DESCRIBED IN THIS REPORT.

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DESCRIPTIONS OF DEPOSITS

The following descriptions of deposits are based on work that ranged from cursory reconnaissance examinations to more detailed field examinations accompanied by laboratory study. Therefore, the amount of information available for the different deposits ranges from relatively little to fairly complete. The amount of data given in the descriptions of the various deposits is not an indication of the relative economic importance of the deposits. Deposits previously described in published reports have been described in this report in condensed form. For more detailed descriptions of these deposits the reader should refer to the articles listed under "Literature cited."

Cochise County

Fluorine Hill deposit

Fluorine Hill is in secs. 33 and 34, T. 17 S., R. 25 E., 2½ miles east of Pearce. The hill is largely composed of partly silicified rhyolite. cut by narrow and discontinuous fractures. Hydrous iron oxides stain most of the fractures and locally the fractures are filled with calcite and hematite. Where exposed in small prospect pits, the carbonate veins are rarely more than 2 or 3 inches wide.

The greatest amount of radioactivity was detected in a prospect pit on the south side of Fluorine Hill near the crest. Exposed in this prospect pit is a narrow carbonate vein that contains a small amount of dark-purple fluorite and flecks of a yellow, uranium-bearing mineral. The uranium-bearing mineral is probably uranophane or autunite. The vein can be traced for less than 25 feet on the surface even with the aid of a scintillation meter to detect slight differences in radioactivity. A grab sample of the vein material exposed in the prospect pit contained 0.11 percent uranium.

The other prospect pits and mine dumps on Fluorine Hill contained no material that was significantly more radioactive than the host rock. A check of fractures exposed at the surface also disclosed no concentrations of uranium-bearing minerals. The rhyolite porphyry host rock is, however, slightly abnormally radioactive in all of the exposures checked on Fluorine Hill and other hills in the area. A representative sample of the rhyolite porphyry contained 0.008 percent eU (equivalent uranium).

It is suggested that the secondary uranium minerals found in the prospect pit on Fluorine Hill were derived either from the host rock and concentrated in the vein by circulating ground water or from primary uranium-bearing minerals that were deposited in the vein from hydrothermal solutions. Inasmuch as fluorite and uranium-bearing minerals are commonly associated in hydrothermal deposits and the only uranium-bearing minerals noted on Fluorine Hill are associated with fluorite, a hydrothermal origin is more probable.

Robles Spring deposit

The Robles Spring deposit is in the SW$\frac{1}{4}$ sec. 30, T. 13 S., R. 19 E., about 30 miles east of Tucson. It was not known to be under claim in 1951 although water rights to the spring are no doubt controlled by one of the nearby ranches.

The deposit is explored by a short adit and a shallow prospect pit. The adit follows a nearly vertical iron-stained shear zone that rolls and merges with the bedding below the adit level. The workings, which were probably dug in search of precious metals, are not related to the radioactive structure.

The uranium-bearing material occurs northeast of the adit along a nearly vertical northwest-trending fault which has placed limestone in contact with schist (fig. 2). The area has received little geologic study and the ages of the rocks are unknown. The limestone, however, is probably Paleozoic and the schist Precambrian. The limestone contains beds of fine crystalline limestone, shaly limestone, limestone pebble conglomerate, and limestone-quartzite pebble conglomerate. The schist is fine-grained, gray, locally calcareous, and contains numerous pegmatitic quartz blebs. The foliation trends slightly west of north and dips about 50° east.

The length and displacement of the fault were not determined but may be relatively large. The fault zone is characterized by local fractures, breccia, iron-stain and lower resistance to erosion and is weakly radioactive along an outcrop length of 100 feet. The greatest radioactivity is in two iron-stained and fractured shale horses in the fault zone. The shale is carbonaceous and the fractures are commonly filled with a powdery yellow iron-sulfate (?). The larger horse is about 15 feet long and 5 feet wide; the smaller is about 10 feet long and nearly 4 feet wide. Iron stain and carbonaceous matter are less abundant in the smaller horse than in the larger.

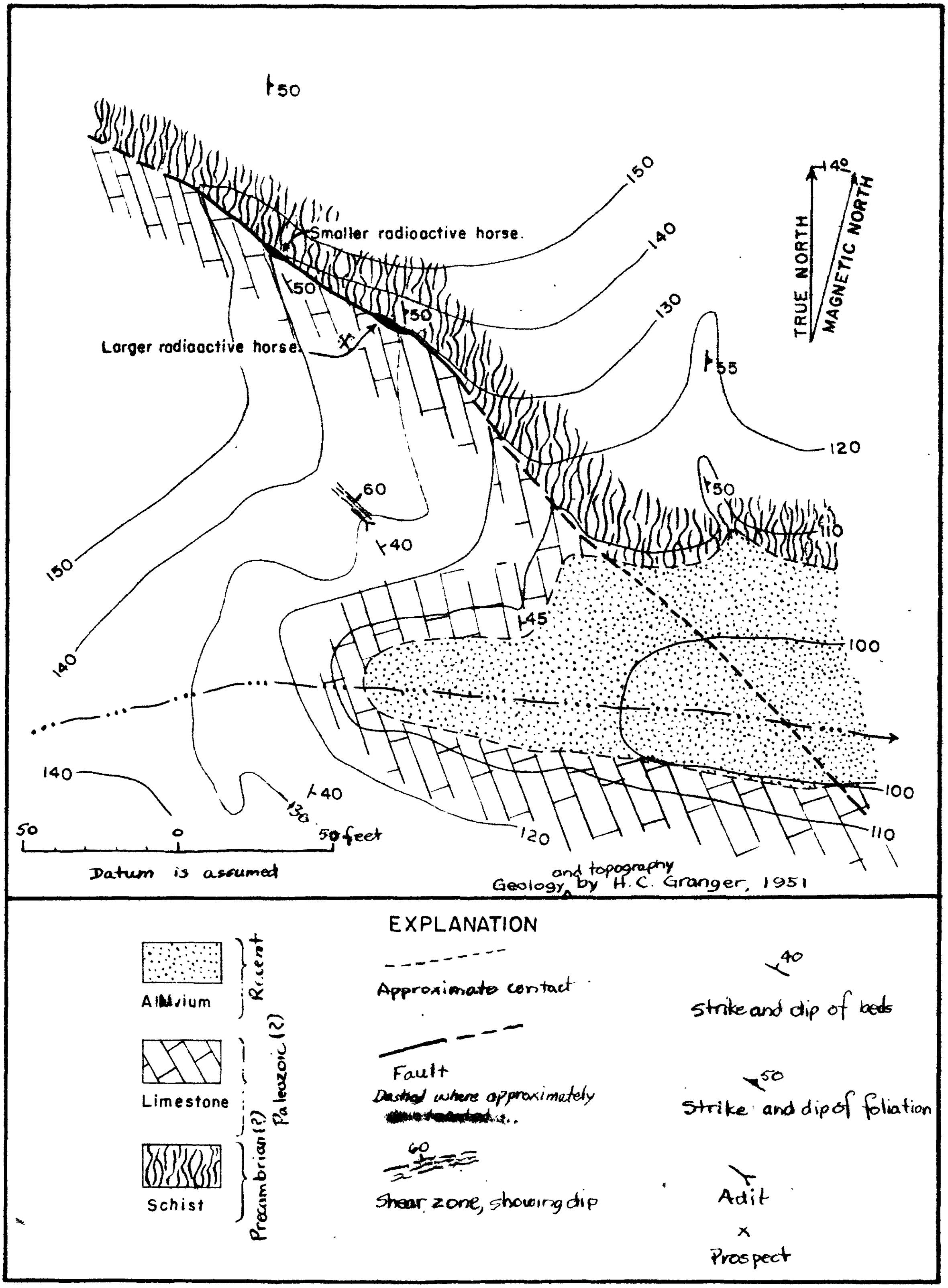

FIGURE 2.-GEOLOGIC SKETCH MAP OF THE ROBLES SPRING DEPOSIT, COCHISE COUNTY, ARIZONA.

A channel sample across the larger horse contained 0.004 percent U and 0.078 percent eU. This suggests that some of the original uranium may have been removed by leaching.

The radioactivity may be the result of solutions percolating in the fault zone or due to material mechanically emplaced by the fault. The source of the carbonaceous shale is not known. Apparently, however, the shale was favorable for precipitation of uranium. Finding the source of the shale is an all-important factor in prospecting for more deposits of the Robles Spring type. It could then be determined if all the shale is radioactive or if the shale accumulated its radioactivity after emplacement in the fault.

Coconino County

Hosteen Nez Mining Company deposits

The Hosteen Nez Mining Company owns several deposits in T. 27 N., R. 12 E., on the Navajo Indian Reservation about 40 miles north-northwest of Winslow. Roman Hubbell of Winslow acted as business manager for the company in 1951.

The two deposits examined are in varicolored shale and sandstone tentatively assigned to the upper Chinle formation. The radioactive material in the northern deposit is exposed in the walls of a draw and occurs near the southern edge of a lens composed of sandy shale, sandstone, and a few clay pebbles. A yellow uranium mineral partly replaces clay pebbles, coats fractures and bedding surfaces, and impregnates manganese-rich concretions and carbonized fossil wood. The manganese concretions are commonly very rich in uranium; one specimen contained 3.88 percent U_3O_8. An 8-foot sample across the radioactive lens, however, contained only 0.035 percent uranium.

Between the northern and the southern deposits uraniferous manganese nodules occur in the float. They evidently weather out of very small, widely-separated concretionary deposits.

The southern deposit caps the summit of a small knoll. Uranium occurs in manganese-rich concretions and in partly silicified fossil wood although locally the sandstone is also radioactive. About 4 tons of hand-picked ore from the surface of the knoll contained 0.20 percent U_3O_8. A selected sample collected by the senior author contained 0.44 percent U.

Orphan claim

The Orphan claim is reportedly the only privately-owned property on the south rim of the Grand Canyon within the National Park. The claim was originally located in 1893 and was patented in 1905, before the Grand Canyon National Park was established. It is on Maricopa Point in sec. 14, T. 31 N., R. 2 E., about 1.5 miles northwest of Grand Canyon Village. The owner in 1951 was Madeline Jacobs of Prescott.

The uranium deposit is in rocks of Permian age about 1,000 feet below the rim (fig. 3). Field relationships suggest that a large block of Coconino sandstone at least 250 feet across has slumped more than 150 feet below the normal contact between Coconino sandstone and the underlying Hermit shale. The slump block is composed of light-colored medium-grained sandstone

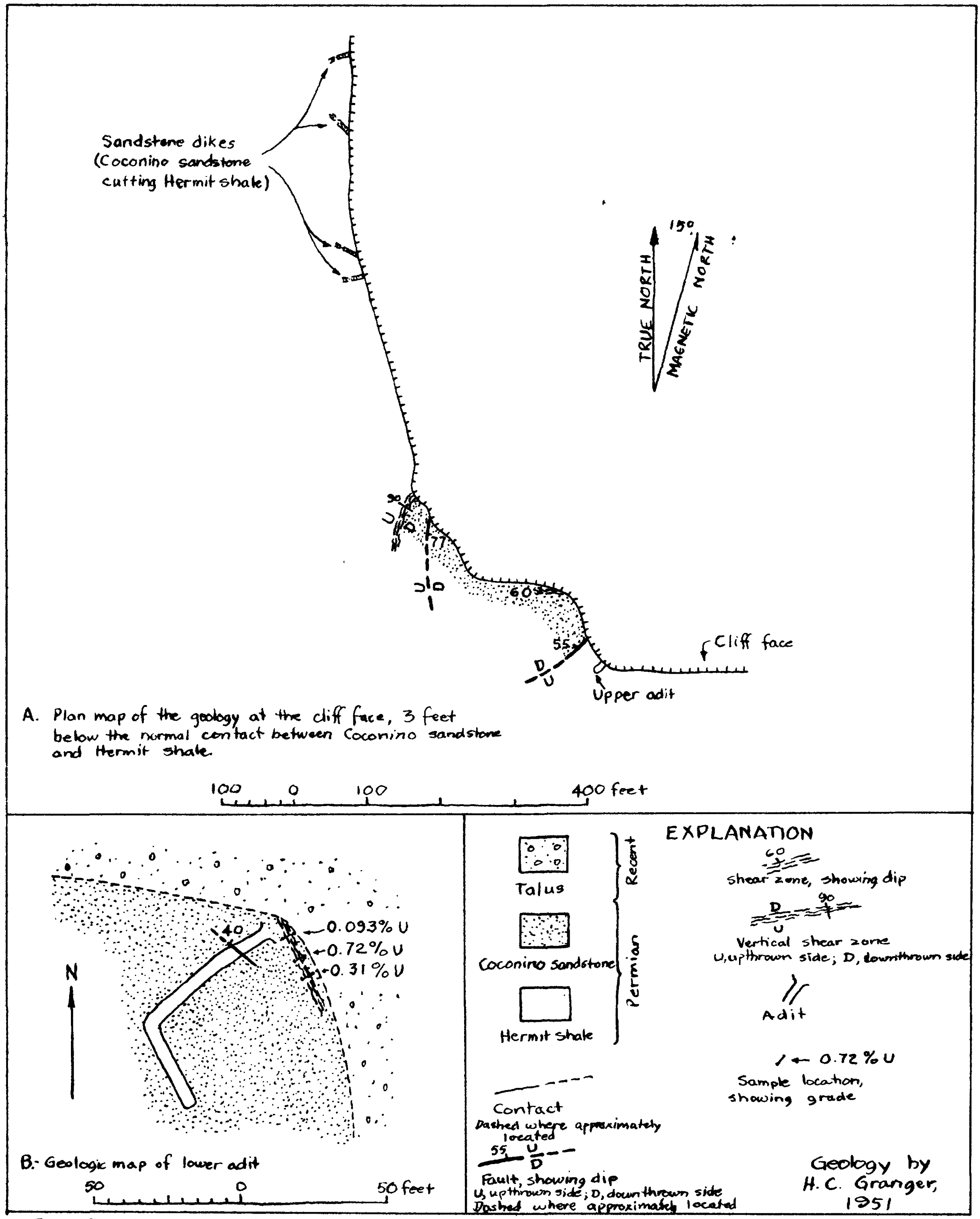

FIGURE 3.-GEOLOGY OF THE ORPHAN CLAIM, COCONINO COUNTY, ARIZONA

in contrast to the brick-red fine-grained sandstone and shale in the Hermit shale. Iron stain and fractures in the block obscure the cross-bedding typical of the Coconino sandstone. The exposed margins of the slump block, where it adjoins the Hermit shale, are marked by iron-stained faults and minor gouge. Most of the fault contact, however, is concealed by talus. The most prominent fault near the northwestern edge of the block strikes N. 10° E. and dips 77° E.; the fault at the southeast edge strikes N. 50° E. and dips 55° NW.

The normal contact between the Coconino sandstone and the Hermit shale is well exposed on both sides of the slump block. The relationships do not seem to indicate a sharply incised scour channel in the Hermit shale although this possibility was originally considered during the field examination.

Three shallow adits on the Orphan claim were driven in search of copper. The upper adit is at the normal contact between Coconino sandstone and Hermit shale about 35 feet southeast of the slump block. It is only 5 feet long, and a small pool of water on the floor suggests that it may have been dug primarily as a source of drinking water for the miners. Small amounts of efflorescent material on the walls are weakly radioactive.

The middle adit is about 80 feet below the normal contact between Coconino sandstone and Hermit shale. It is in Coconino sandstone along the southeast margin of the slump block. The main drift trends S. 20° W. for about 25 feet and is joined near the portal by a branch drift about 15 feet long. The sandstone in the adit is cross-bedded and fractured. Near the portal is a conspicuous fracture that strikes N. 15° W. and dips 50° W.

The dip flattens until it is nearly horizontal a few feet inside the portal. Malachite and iron oxides stain this fracture although most of the other fractures show little or no filling or stains by either copper or iron minerals. The sandstone contains blebs and streaks of copper sulfates, chrysocolla, hematite, and minor sulfides. The walls of the adit are covered with an efflorescent coating of iron and copper minerals associated with gypsum.

Radioactivity in the adit averages about 0.5 mr/hr. Readings as high as 5.0 mr/hr were recorded. A sample, composed of chips taken every 5 feet along the walls of the adit, contained 0.043 percent U and 0.064 percent eU.

The lower adit is in the lowest exposed part of the slump block about 150 feet below the normal base of the Coconino sandstone. The adit trends S. 55°-60° W. for 45 feet, then turns sharply S. 28° E. for 25 feet. Nearly all the sandstone in the adit is impregnated with pyrite, arsenopyrite, chalcopyrite, and hematite; minor chrysocolla and copper sulfates occur near weathered surfaces. The sandstone contains many irregular post-mineral fractures. The most persistent fractures and the adit walls are coated with gypsum, minor chalcanthite or brochantite and perhaps other efflorescent sulfate minerals.

Radioactivity is strong at the portal but decreases immediately within the adit. A sample composed of chips taken every 10 feet along the walls of the adit contained only 0.006 percent U.

Immediately outside the portal of the lower adit is a shear zone about 5 feet wide composed of subparallel, intensely iron-stained fractures that locally contain metatorbernite. The shear zone is nearly vertical, strikes N. 25° W., and may be traced for about 25 feet to the southeast where it becomes indistinct at the edge of the slump block. Northwest of the portal it is covered by talus. The adit was apparently started in the shear zone but was excavated nearly normal to its trend.

Radioactivity is very strong in the shear zone. The highly iron-stained rock and surfaces coated with torbernite are the most radioactive. Three channel samples cut across the shear zone assayed from 0.093 to 0.72 percent U and from 0.21 to 1.00 percent eU. Black, sooty, unidentified material, which locally impregnates the sandstone in the shear zone, is less radioactive than the surrounding rock. The average radioactivity in the shear zone is about 0.5 mr/hr. At least one area about 3 feet across on the southwest wall of the shear zone is too radioactive to measure with a field counter. This rock has been strongly leached and contains only 0.039 percent U; the radioactivity is equivalent to over 12.5 percent U.

The entire surface of the slump block is abnormally radioactive. The rock is highly iron-stained and fractured and the most radioactive zones are along fractures which probably carry surface and percolating meteoric waters after rains. Many of these fractures show radioactivity up to 1.5 mr/hr. The major fault along the northwest margin of the slump block locally gives readings of 0.5 mr/hr.

A detailed examination of the most radioactive rock from the shear zone, by S. Molloy, U. S. Bureau of Mines in Tucson, indicated that radioactive lead might be present. The sample subsequently was found to contain 3.58 percent lead and a lead button derived from the sample was highly radioactive. These results suggest that the rock has been intensely leached and that the lead was derived, in part, as an end product of uranium disintegration.

The high radioactivity in the shear zone and the evidence of intense leaching suggest that the uranium content may improve substantially only a few feet below the surface. Below this zone of surface weathering primary uranium minerals are probably present for the following reason. The origin of the uranium and other minerals is unknown; but, if the uranium minerals and the sulfides that permeate part of the slump block are genetically related, then the presence of pyrite, chalcopyrite, arsenopyrite, and hematite indicate an ultimate hydrothermal source.

The senior author, who examined the property, further believes that alteration preceded the slumping of the Coconino block. The processes of alteration and perhaps mineralization may have softened and weakened the sandstone so that it was not competent to stand as a cliff face when exposed during the erosion of the Grand Canyon.

This deposit is markedly similar to Hack's mine (p. 32). Both occur near the contact between Coconino sandstone and the Hermit shale. At both deposits the overlying Coconino sandstone has slumped at the cliff face. The radioactivity is strongest in the Coconino sandstone but may extend into the underlying Hermit shale.

Since the senior author examined the property, the U. S. Atomic Energy Commission has explored the Orphan deposit. The results of drilling are not known to the writers.

Gila County

Dripping Spring quartzite

The Dripping Spring quartzite is extensively exposed in southeastern Arizona, but uranium deposits of economic significance are known only in Gila County, particularly the north-central part. Uranium deposits in the Dripping Spring were first noted in early 1950, but they remained poorly known until late 1953. At the time of this writing the authors were conducting a study of these deposits, and, accordingly, the descriptive material contained herein is more complete than that of most of the other deposits.

Deposits in the Dripping Spring received very little study prior to 1953, but have been thoroughly investigated since that time. Workers include R. J. Wright (1950a), E. P. Kaiser (1951a), W. E. Mead and R. L. Wells (1953), R. G. Gastil (1953), R. L. Wells and A. J. Rambosek (1954), D. N. Magleby and W. E. Mead (1955).

By 1956 about 100 uranium deposits had been found in the Dripping Spring. Of these, less than a dozen were being actively developed, but about 40 had been explored by drilling or drifting in addition to the required assessment work.

The Dripping Spring quartzite is a formation in the relatively unmetamorphosed Apache group of younger Precambrian age. The Apache group lies nonconformably on gneiss, schist, and granitic rocks of older Precambrian age and is overlain disconformably by Paleozoic rocks.

The Apache group is extensively intruded by diabase, which typically occurs as large sills but locally forms dikes, gently crosscutting sheets, and other irregularly shaped bodies.

The Dripping Spring consists of two members. The lower member is typically a reddish arkosic to orthoquartzitic sandstone. It is missing in the extreme northern part of Gila County where it abruptly overlaps older rocks, but it ranges in thickness from 140 to 370 feet elsewhere in the County.

All the known uranium deposits in the Dripping Spring quartzite are in the upper member, which is much finer grained and more thinly stratified than the lower member. It is typically an arenaceous siltstone but contains units that range from shale to coarse-grained orthoquartzite. The uranium deposits generally occur in a gray siltstone unit near the middle of the upper member, although secondary deposits are not uncommon lower in the member.

The siltstone unit favorable for uranium deposits has several unique characteristics. It is abnormally potassia-rich, ranging from about 10 to 14 percent. The potassium apparently occurs in detrital feldspar grains. Where unweathered, the unit is generally colored gray due to as much as 2 percent of extremely fine-grained carbon. A minor amount of disseminated pyrite also contributes to the gray color. Where cut by large diabase bodies, the favorable siltstone unit is locally metamorphosed to hornfels and related rocks. The hornfels is seemingly more favorable for uranium deposits than is the normal unmetamorphosed siltstone.

The primary deposits are generally vein-like in form and nearly vertical. They are limited vertically by favorable lithology and rarely exceed 20 feet although deposits with vertical dimensions of as much as 80 feet have been reported (R. J. Schwartz, written communication). They are ordinarily less than 5 feet wide and range from about a hundred to more than 300 feet in length. The maximum length has not yet been determined. Favorable strata are locally ore-bearing laterally from the central veinlike body and these may form manto-like deposits.

Most deposits trend within a few degrees of N. 70° W. or N. 20° E. They parallel the trends of a strong joint system in the Dripping Spring in northern Gila County. At the surface one of these limonite-filled joints commonly follows the deposit but farther underground the joint is unrecognizable or diverges from the trend of the deposit. It appears that the joints, as now seen, are controlled by rather than control the deposits. Perhaps they are more recent manifestations of earlier tight joints along which the deposits were emplaced.

In some of the deposits in hornfels the ore minerals are localized along breccia zones cemented by an aplitic rock suspected to be a mobilized facies of the hornfels. These breccia zones, at least those that are ore-bearing, are parallel to the joint system described above.

Uranium minerals are generally disseminated in the deposits but locally form short veinlets and irregularly shaped masses, particularly in the hornfels near diabase bodies.

The primary uranium mineral in deposits adjacent to diabase is uraninite in extremely fine discrete grains. Aggregates of these grains locally form masses that appear to be massive uraninite but microscopic examination invariably discloses a multitude of uraninite grains disseminated in a clay-rich matrix.

Coffinite in association with uraninite was identified by X-ray in one specimen, but it is probably rare.

No primary uranium mineral has been identified from deposits not adjacent to diabase. Although extremely fine disseminated uraninite may exist in these deposits, it is probable that much of the primary uranium was adsorbed on other minerals such as clay and graphite.

Sulfide minerals are generally abundant in the deposits and probably formed later than the uranium minerals. In hornfels, molybdenite, pyrrhotite, chalcopyrite, marcasite, pyrite, galena, and sphalerite are present in approximately that paragenetic sequence. No molybdenite or pyrrhotite has been noted in deposits in siltstone but all the other sulfides present in the hornfels have been identified.

Secondary parts of deposits in hornfels contain abundant uranophane and sparse metatorbernite, associated with secondary copper and iron minerals, minor uraniferous hyalite, and gypsum. In the secondary parts of deposits in unmetamorphosed siltstone, torbernite is the most abundant uranium mineral.. Bassetite, uranophane, uranocircite, and uraniferous hyalite have also been identified. Other secondary minerals are similar to those in the hornfels.

The spatial relationship of these deposits to diabase suggests a genetic relationship also. The association in metamorphosed host rocks of sulfide minerals such as molybdenite and pyrrhotite, which are generally considered to have high temperature affinities, also points to contemporaneity and genetic relationship to the diabase. Analyses of various facies of the diabase suggest that it has lost uranium during its cooling history. If the uranium content of chilled borders of the diabase represents approximately the original uranium content of the magma, it can be shown that the normal diabase in the interior of the bodies and the various more silicic differentiates do not contain enough uranium to account for all of the uranium originally present in the magma. There is no evidence to indicate that the chilled border was enriched in uranium from the enclosing sedimentary rocks.

Tentatively, it is concluded that uranium-bearing solutions were expelled from the diabase at a late magmatic stage. The solutions percolated through the surrounding rocks following permeable strata and tight joints till they came in contact with rocks rich in original carbon and pyrite, or carbon, pyrite, and clay. Here, under the influence of strongly reducing and adsorptive conditions the uranium was concentrated.

Graham County

Golondrina claims

Pyromorphite, a lead chloro-phosphate, occurs as a radioactive fracture filling associated with minor quartz and limonite on the Golondrina claims in the S. $\frac{1}{2}$ sec. 12, T. 11 S., R. 25 E. (Granger, 1951). A block of 21 claims was held by M. V. Lee, Dragoon, Arizona in 1951.

Porphyritic volcanic rocks in the vicinity of the prospect are underlain by a medium-grained granite locally intruded by rhyolite dikes. The pyromorphite deposits apparently were localized, at least in part, by a 1- to 2-foot layer of agglomerate or flow breccia that separates two successive porphyry flows. The pyromorphite occurs in cavities and fractures in the breccia and also in fractures in the porphyritic rocks near the breccia layer. A short adit follows the breccia for about 20 feet and two open pits apparently expose the basal part of the upper porphyry flow. In the larger open pit, traces of chalcopyrite, pyrite, chalcocite, and malachite are associated with the pyromorphite.

The radioactivity is not necessarily in direct proportion to the quantity of pyromorphite, suggesting that the uranium content of the pyromorphite is variable. Tests by the U. S. Atomic Energy Commission indicate that the pyromorphite contains as much as 0.6 percent U (Wright, 1950b), probably as part of the mineral composition. A sample tested by the U. S. Bureau of Mines (Faick, 1953) contained 0.26 percent eU_3O_8 and 0.221 percent U_3O_8. Although widespread, most of the radioactive material is of very low grade.

Maricopa County

Black Mountain claims

A group of claims named the Black Mountain and Black Mountain Vanadium were staked for uranium on the west end of the Vulture Mountains, about 12 miles southeast of Aguila. The claims were owned in 1951 by Milton Ray of Aguila. Several prospect pits and trenches explore the deposits to shallow depths.

The uranium deposits occur in shaly beds of buff to white limy bentonitic tuff between 100 and 200 feet thick. These tuffs form a northwest-trending cuesta capped by a basic lava flow and underlain by gneiss and schist that are locally cut by pegmatite dikes. The strata strike N. 60°-65° W. and dip as much as 50° SE. The average dip is 10°-20° SE; steeper dips are commonly caused by slumping. Gypsum and a yellow uranium mineral, probably carnotite (Hewett, 1925), sparingly coat fracture and bedding plane surfaces.

Although much of the tuff probably contains traces of carnotite for a distance of a mile or more, the grade is extremely low. A "high grade" sample recorded by Hewett contained only 0.009 percent U_3O_8.

Lucky Strike claim

The Lucky Strike claim, about 13 miles by road north of Morristown, was owned in 1951 by John Richie and James Russell of Morristown. A 60-foot adit on the claim develops a narrow vein in Precambrian Yavapai schist.

Several tons of radioactive material on the dump were mined from a quartz fissure vein at least 8 inches wide. Paradoxically, no evidence of a radioactive vein of this size or type can be found in the adit. The material on the dump contains galena, chalcopyrite, wulfenite, chrysocolla, chalcocite, willemite (?), and pyromorphite (?) in a quartz gangue. One grab sample of this material contained 0.025 percent U.

The vein quartz on the dump has been broken clean of its wall rock, and this makes it difficult to determine the source. Perhaps the complex ore occupied a pod or pocket in the schist along an otherwise inconspicuous vein. Possibly the material was not derived from this mine.

Mohave County

Catherine and Michael claims

The Catherine and Michael claims are on the western escarpment of the Aquarius Cliffs about 8 miles east of the road between Kingman and Wikieup and are 50 miles southeast of Kingman. They were owned in 1951 by R. H. Carr and others of Los Angeles, California.

The Aquarius Cliffs face westward and overlook a fault trough valley formed by the downthrow of a mountain block on the west. For the most part, the Aquarius Cliffs — which are rugged slopes rather than cliffs — are composed of Precambrian granite, gneiss, and schist intruded by numerous dikes ranging from aplite to pegmatite in composition. The crest and parts of the escarpment of the Aquarius Cliffs are covered by lava and pyroclastic rocks. The lower slopes of the Aquarius Cliffs are composed chiefly of valley fill and terrace gravels.

The Catherine and Michael claims lie along a valley sharply incised into the escarpment of the Aquarius Cliffs (fig. 4). On the east wall of the valley are a series of tilted sandstones, shales, and limestones that overlie the granite basement rocks. Flat-lying arkosic grit and conglomerate strata form the west wall of the valley; these strata are locally unconformable on the steeply dipping beds beneath. Several hundred feet north of the claims a fine-grained basic extrusive or sill, containing limestone inclusions, is exposed above the tilted sediments.

Detailed study of the rocks in the Aquarius Cliffs has been neglected by all the regional studies of the past. Lee (1908) and Schrader (1909)

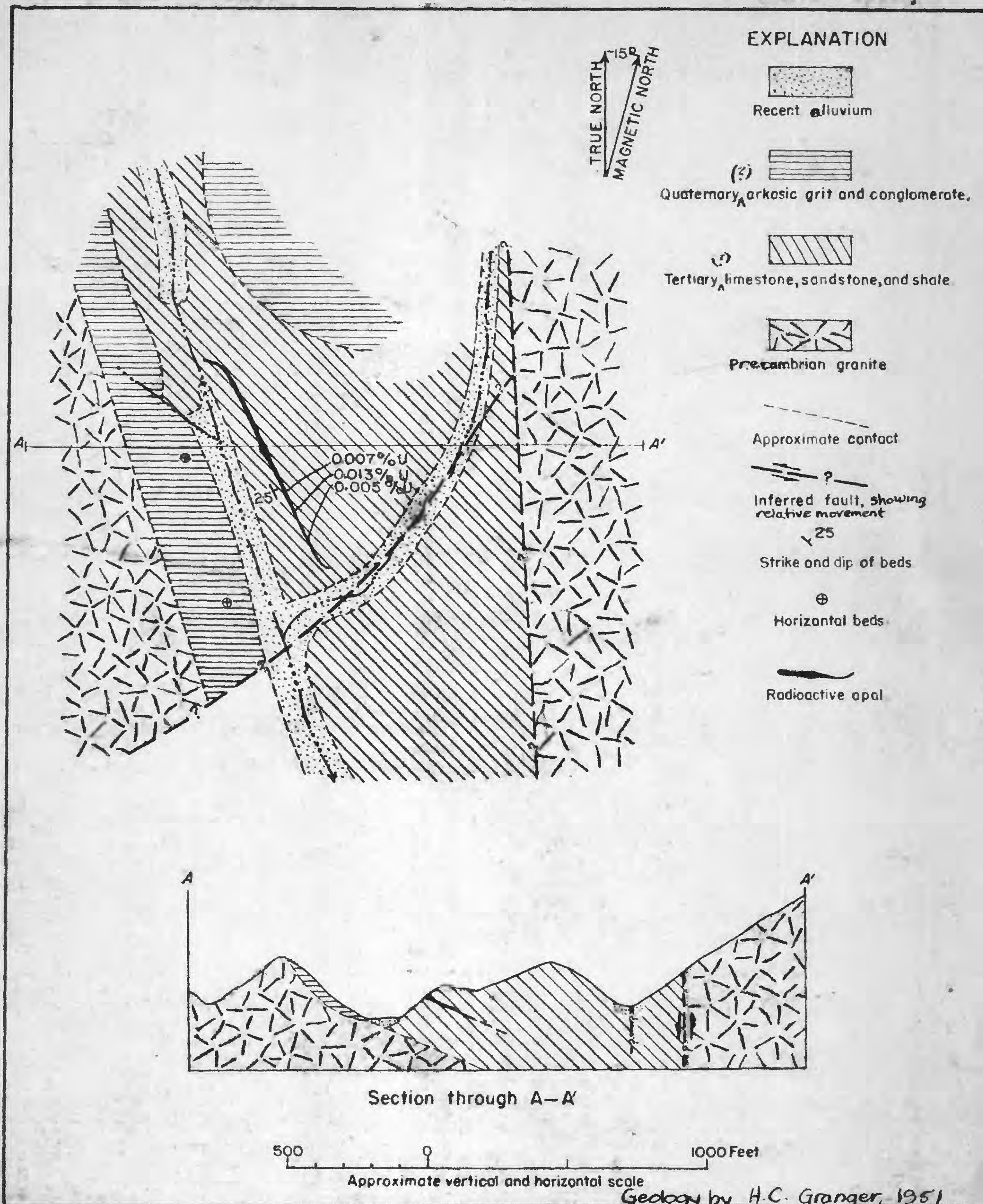

FIGURE 4.-GEOLOGIC SKETCH MAP, CATHERINE AND MICHAEL CLAIMS, MOHAVE COUNTY, ARIZONA.

briefly discuss the areal geology of the region, but no mention is made of the tilted sediments on the slopes of the Aquarius Cliffs. Wilson (1941) gives a brief resume of the geology of the Aquarius Cliffs as it pertains to the pegmatites and veins that contain tungsten minerals. Morrison (1940) mentions tilted lake bed deposits that contain concretionary limestone, volcanic ash, gypsum, analcite-bearing sandstone, diatomite, and bentonite, locally interbedded with basaltic lavas. These are probably the rocks in which the Catherine and Michael uranium deposits occur. Morrison's map, however, shows only the granitic basement rocks at the Catherine and Michael claims. Morrison does not give the age of any of the rocks and the senior author can state only that the "lake beds" are earlier than the latest period of faulting.

The uranium deposits occur in a thinly-laminated poorly-consolidated limestone unit that strikes N. 20°-30° W., dips 25°-30° NE., and is 20 to 30 feet thick. The limestone conformably overlies a series of sandstones and shales and is disconformably overlain by arkosic grit and conglomerate. The limestone is locally replaced by white opal and fluorescent green opal that are commonly stained by black irregular patches of manganese oxide. Apparently the greenish opal, which displays the brightest fluorescence, is also the most radioactive; the white milky opal is virtually non-radioactive. The greenish opal, although less common than the white opal, is scattered throughout a layer as much as 10 feet thick along a strike length of nearly 800 feet in sufficient quantity to make almost the entire layer radioactive. Perhaps the uranium is held as ions within the opal molecular lattice as no uranium minerals were identified in the radioactive material.

A small selected specimen of fluorescent green opal contained 0.2 percent U. This is much higher than the average uranium content of the deposit, but it gives an indication of the amount of uranium that can be contained in opal without the formation of obvious uranium minerals. Three channel samples believed to be representative of the uraniferous rock contained from 0.005 to 0.013 percent U very nearly in equilibrium.

Hack's mine

Hack's mine, also known as the Hack Canyon uranium mine, is on a group of five claims named Hack's and Hack's No. 2 through No. 5. The claims are in Hack Canyon in sec. 26 (?), T. 37 N., R. 5 E., about 37 miles by road southwest of Fredonia. The claims were acquired in 1940 by Clair Pearson, A. E. Jenson, and three associates, all of Fredonia. Only the deposits on Hack's and Hack's No. 2 claims were examined by the senior author.

The deposit at Hack's mine is explored by a 30-foot shaft, a 45-foot adit, two inclined shafts, and over 200 feet of drifts and crosscuts (fig. 5). Small amounts of copper ore have been produced from the mine at various times since 1920. Uranium minerals were discovered while the mine was being worked for copper late in World War II (Dunning, 1948).

Upper Hack Canyon cuts a series of Permian sedimentary rocks from the Hermit shale to the Kaibab limestone. The outcrop of the copper-uranium deposit on Hack's claims is on a steep talus slope just below the normal contact between cliff-forming Coconino sandstone and Hermit shale. Much of the talus is composed of Coconino sandstone and may be underlain, in

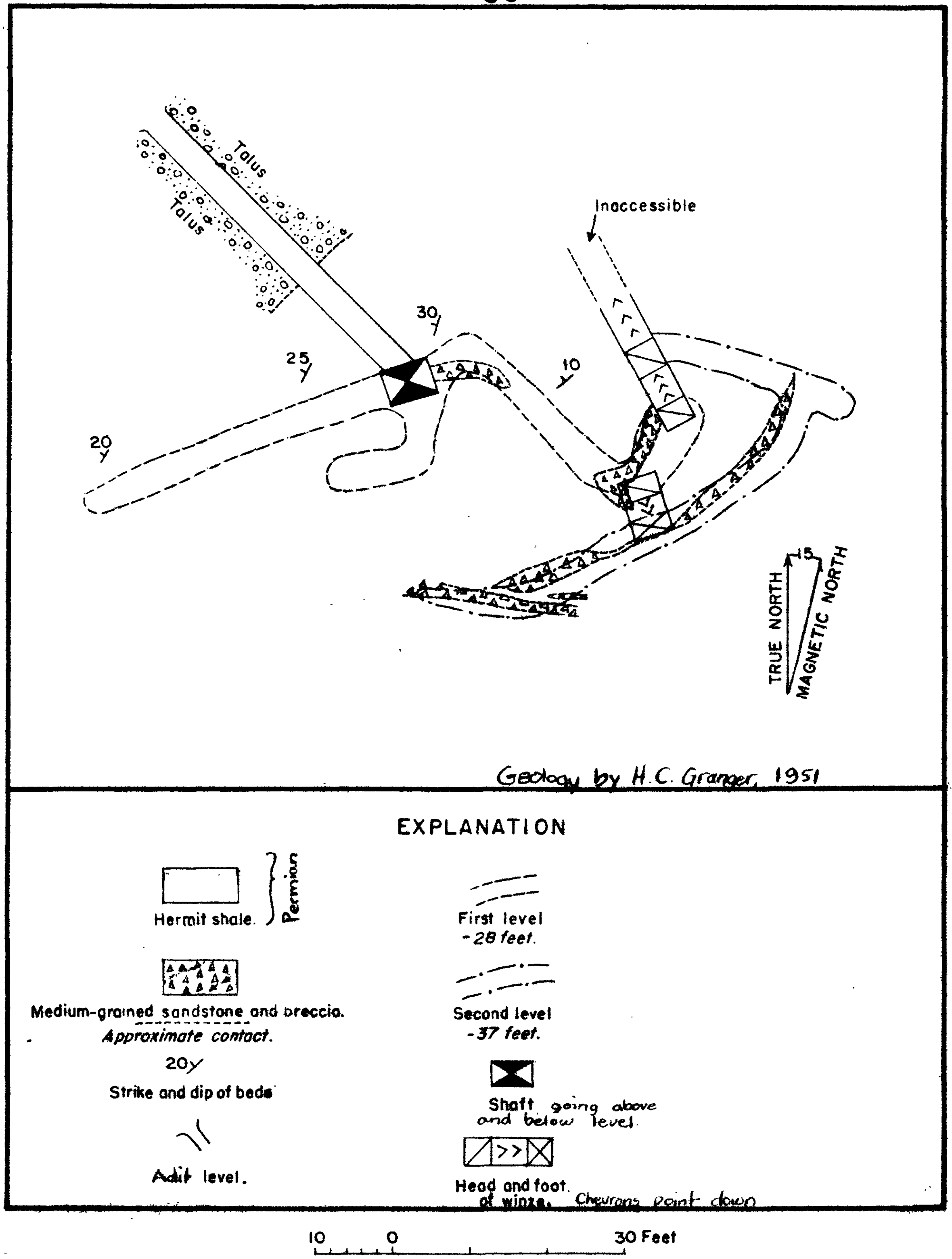

FIGURE 5.—COMPOSITE SKETCH OF WORKINGS, HACK'S MINE, MOHAVE COUNTY, ARIZONA.

part, by a slump block of Coconino. The presence of this talus and slumped material at the outcrop of the deposit has prompted earlier investigators to state that the Hack's deposit is localized primarily in a slump block.

At the surface, many fractures in the broken, slumped Coconino sandstone are stained with green copper minerals and minor quantities of metatorbernite. This layer of broken, slumped material is less than 20 feet thick. Underlying the talus is a large volume of bleached Hermit shale. The most obvious distinction between bleached Hermit shale and normal Coconino sandstone is the grain size; Coconino sandstone is medium grained and Hermit shale is a fine-grained sandstone rather than a shale. Coconino sandstone is commonly crossbedded, but the Hermit shale is thin- and flat-bedded with individual beds up to 2 feet thick.

In Hack's mine, beneath about 15 feet of talus and slumped material, the rock is, for the most part, fine-grained, indistinctly bedded, dirty gray, and locally silicified. Near the southwest face of the first level the dirty gray, altered rock grades into normal, red, unaltered Hermit shale. No structural break divides the red from the dirty gray rock; hence, it is believed that most of the rock explored by the Hack's mine is Hermit shale.

Several zones within the mine contain a breccia consisting of fragments composed of both fine- and medium-grained sandstone in a matrix of predominantly fine-grained sandstone. These zones locally follow bedding planes or dip steeply with elongate trends and extremely obscure margins. The breccia was apparently cemented under considerable pressure as no cavities remain.

The brecciated zones and areas of coarser-grained sandstone have become the loci for primary minerals. The breccia commonly has a light-reddish hue, probably from iron oxides, and locally contains black spots that are markedly radioactive. The black spots probably consist of chalcocite and minor pitchblende (Gruner, 1950). No other metallic sulfides were identified, but they were undoubtedly present before weathering affected the rock. Fractures in the breccia locally are coated with chalcanthite, brochantite, erythrite or bieberite, and one or two yellow uranium minerals, perhaps including zippeite. Farther out, in the altered, fine-grained sandstone, malachite and metatorbernite occur along fractures and bedding planes and as impregnations which fill the interstices of the sandstone.

Nine samples taken during this examination contained from 0.004 to 0.28 percent U. The higher uranium content was encountered mainly in the breccia zones. Efficient mining of the deposit would necessitate knowing how to find and how to follow these breccia zones.

About 500 tons of rock, on a dump near the portal of the tunnel in 1951, was radioactive. The radioactivity was measured about 2 feet from the surface with a portable field meter with a 6-inch probe and was found to average about 0.10 mr/hr. The senior author estimated the reading to be equivalent to nearly 0.1 percent U. Ore containing 0.1 to 0.2 percent U could be recovered by hand-cobbing.

A small amount of a pale-yellow powdery uranium mineral was recovered from a prospect pit on Hack's No. 2 claim about 500 to 600 yards northeast of Hack's mine. The mineral is unidentified but spectrographic analyses show that it contains significant amounts of uranium, silica, and phosphate. It occurs along joints and bedding planes in a shaly facies near the contact between Coconino sandstone and Hermit shale, probably in the Hermit shale.

This prospect pit on Hack's No. 2 claim has not uncovered an economically significant uranium deposit, but it demonstrates the widespread occurrence of uranium in the area of Hack's mine.

The identity of the host rock for the uranium deposit at Hack's mine has been a puzzle. Dunning (1948) believed the ore occurs in a slump block of Coconino sandstone lying on Hermit shale. As previously stated, however, the senior author believes most of the ore lies below the surficial talus and slump block.

An examination of one thin section of the host rock disclosed that many of the quartz grains were enlarged by authigenic overgrowths. The size of the quartz grains in the medium-grained sandstone may, therefore, be a result of secondary enlargement; the sandstone may be silicified Hermit shale. The senior author, prompted by a discussion with A. C. Waters, believes that it is possible that this silicification has taken place along fractures and permeable beds in the Hermit shale. These zones may then have been brecciated by subsequent movement along the fractures or by some obscure process of autobrecciation.

It is also possible that the medium-grained material is actually Coconino sandstone. Sandstone dikes of Coconino sandstone intruding the Hermit shale or Supai formation are not uncommon, and it is conceivable that the breccia bodies represent brecciated sandstone dikes.

The evidence is too inconclusive to state dogmatically that either of these processes prevailed; the ideas are merely advanced to stimulate the thought of succeeding investigators.

Many features of this deposit are markedly similar to those of the Orphan claim, described on page 16.

Jim Kane mine

The Jim Kane mine is in sec. 8, T. 22 N., R. 17 W., in the Wallapai district, about 10 miles north of Kingman (Kaiser, 1951b). It was owned in 1951 by Jim Kane who lived at the mine.

The Jim Kane mine consists of three adit levels in a wide shear zone that strikes N. 60° W. and dips steeply to the northeast in Precambrian gneiss. Individual veins and shears within the major shear zone contain scattered galena and sphalerite in a siderite gangue. One of the veins, about 3 feet wide, contains small amounts of radioactive material. Radioactivity is weakly traceable for about 120 feet along the vein on the middle level and more strongly for about 60 feet horizontally along the same vein in a stope 23 feet above the level. The abnormal radioactivity coincides with a part of the vein that is reported to contain over 5 percent lead as compared to 1 percent or less elsewhere. No uranium minerals were recognized although the U. S. Bureau of Mines reported pitchblende to be present (R. J. Wright, oral communication). Chalcedony and gypsum that locally coat the mine walls fluoresce yellow-green and bright red, respectively.

Two samples taken by Kaiser (1951b) are believed to represent the grade of the vein at the richest part of the ore shoot; they contained 0.067 and 0.042 percent uranium respectively. Rambosek and King (1952) took two samples from unreported localities in the mine; the samples contained 0.003 percent U_3O_8 and 0.006 percent U_3O_8 respectively.

Red Hills prospect

The Red Hills uranium prospect is in sec. 7, T. 11 N., R. 13 W., about 6 miles northwest of the old settlement at Alamo. The claims were owned by E. W. Tate of Wenden in 1951.

Rocks in the area of the Red Hills prospect consist chiefly of the Artillery formation, probably of Eocene age, underlain by Precambrian schist and gneiss (Kaiser, 1951c). Nearby exposures suggest that the Artillery formation has been thrust over the Precambrian rocks at a low angle. The Artillery formation in the prospect area is a breccia containing fragments of schist, felsitic material, conglomerate, and limestone cemented by silica, carbonates, and manganese oxide. It is probably a fault breccia related to the low-angle thrust fault, but it may be, in part, a sedimentary breccia at the base of the Artillery formation (Lasky and Webber, 1949).

A prospect pit was sunk on a radioactive shear zone that strikes N. 55° W., dips 70° SW., and is 305 feet wide. Three similar shear zones, two of which contain radioactive material, are exposed southwest of the pit. Barite, fluorite, and copper stain cement brecciated rock in the shear zone exposed by the prospect pit. Much of this material is radioactive and two samples taken from the dump contained 0.12 and 0.14 percent U although no uranium minerals were recognized.

Traverses made with a scintillation survey meter outlined a zone of radioactivity that trends easterly through the prospect pit for about 300 feet and crosses the structural pattern defined by the shear zones. The most radioactive areas are where the shears cross the radioactive zone. Inasmuch as the zone of radioactivity apparently crosses structural trends and the Artillery formation is presumably quite thin at the Red Hills prospect the extent of the deposit cannot be predicted with any reliability.

Summit mine

The Summit mine is in sec. 32, T. 23 N., R. 17 W., about 15 miles north of Kingman. The Summit vein is a composite vein zone which ranges from 20 to 30 feet wide. The zone strikes approximately N. 40° W. and dips steeply to the northeast. Host rocks for the vein are gneissoid biotite granite and a few narrow basic dikes that intruded the granite.

Mine workings include drifts on 3 levels entered by a shaft and 2 crosscut-adits. The 300-foot shaft connects with drifts on the 160- and 300-foot levels and one of the adits intersects the 160-level near the shaft. The other adit intersects the vein on the 500-foot level of the mine and connects with 350 feet of drifts. A 30-foot raise has been driven from the drift.

Lead, zinc, copper, gold, and silver minerals are present in the vein material, but no uranium minerals were identified. Inasmuch as the highest radioactivity detected was from material that contains sooty chalcocite, it is possible that finely divided uraninite occurs with the chalcocite.

The only significant radioactivity detected on the property is on the 500-foot level of the mine. Scintillation survey meter traverses of the drift and raise indicated the presence of a small amount of radioactive material in the exposed vein. The most radioactive areas are at the top of the raise and in a 20-foot exposure of the vein between 130 and 150 feet southeast of the crosscut adit. Geiger counter readings at these spots were as much as twenty times background radioactivity.

On the basis of radioactivity, it is doubtful that commercially minable quantities of ore grade rock are exposed in the mine workings examined. Selected specimens of the sooty material exposed in the 500-foot level of the mine may contain as much as 0.2 percent U or possibly more, but only in very small quantities.

Navajo County

Anna Bernice claims

The Anna Bernice Nos. 1 to 5 claims are 6 miles north of Joseph City and were owned by D. O. Roller of Wickenburg and L. W. Kowalski of Phoenix in 1951.

Two shallow prospect pits have been dug in a thin jasper lens in flat-lying bentonitic shale in the Chinle formation of Triassic age. The jasper lens is about 6 inches thick and about 150 feet in diameter. Most of the lens is exposed by the erosion of the overlying shale so that it covers the surface of a small bench. The jasper is dark brown and shows relict fragmental structure. The darkest material seems to be the most radioactive. One specimen displayed a few specks of a yellow uranium mineral on a fracture surface, but not in a quantity sufficient to account for the uranium content of the deposit.

Three representative samples contained 0.025, 0.026, and 0.043 percent U, and a high-grade specimen contained 0.25 percent U.

It is believed by the senior author that the uranium in this deposit was derived from the surrounding Chinle formation, a large part of which is now a montmorillonitic clay derived from volcanic ash. It is postulated that during the devitrification of the ash there was loss of silica, iron, uranium, and alkali metals. The silica and iron selectively replaced a conglomeratic lens of fragmental material forming an iron-rich jasper. Most of the uranium was redeposited in the jasper in very minute fractures invisible to the naked eye (T. G. Lovering, 1956, written communication).

Petrified Forest area

During routine traversing with a car-borne Geiger counter in March 1951, a small low-grade uranium deposit was found inside the southern boundary of the Petrified Forest National Monument. The deposit is exposed in a road cut on both sides of U. S. Highway 260, 1.1 miles west of the south gate to the Monument.

Although the Arizona state geologic map (Darton and others, 1924) shows the area of the deposit to be covered by the Moenkopi formation, it is believed that the deposit is in the lower Chinle formation, or the Shinarump conglomerate. The varicolored shales and abundant petrified wood are more diagnostic of the Chinle formation than of the Moenkopi or Shinarump.

The radioactive material is coincident with fragmental carbonized vegetal material in a sandy shale lens about 5 feet thick and more than 125 feet across. Two representative channel samples contained 0.012 and 0.015 percent uranium. An abundant non-radioactive powdery yellow material associated with the vegetal material and impregnating the enclosing rock is believed to be an iron sulfate.

Tract No. 1

Tract No. 1 consists of 21 acres owned by the New Mexico and Arizona Land Company in 1951 and leased to Frank A. DoBell of Holbrook. The tract is along the west boundary of the Petrified Forest National Monument in the SE¼ sec. 1, T. 17 N., R. 23 E., about 3 miles west of the First Forest in the northern part of the Monument.

The uranium deposit is in flat-lying buff-colored sandstones, clays, and conglomerates of the Chinle formation of upper Triassic age. The strata contain abundant carbonized and petrified fossil plant remains. The petrified material is commonly in the form of buff-colored tree limbs and trunks and is non-radioactive. The carbonized material generally consists of fragments or small, flattened, lenticular masses, but in some cases it is directly associated with the petrified material; some of the petrified limbs have an outer shell of carbonized wood as though the limb had been charred before deposition. Perhaps the fragments of carbonized wood represent charred twigs and bits of charcoal ripped from the surfaces of burnt logs and limbs during the process of deposition. Radioactivity is roughly proportional to the amount of the carbonized material.

The uranium-bearing lens is about 125 feet long and is exposed on both sides of a sharp ridge. The lens reaches a maximum thickness of about 8 feet but tapers off sharply to less than 2 feet. Two channel samples contained 0.008 and 0.017 percent U, but individual fragments of carbonized material are much richer.

Tract No. 2

Tract No. 2 covers 41 acres about 20 miles southeast of Holbrook. It was owned by the New Mexico and Arizona Land Company in 1951 and was leased to Frank A. DoBell of Holbrook. The tract is in the SE¼ sec. 33, T. 16 N., R. 23 E., about 3 miles south of the Petrified Forest National Monument. The Arizona state geologic map (Darton and others, 1924) indicates that Tract No. 2 is in the Triassic Moenkopi formation. The lithology is very similar to the sandy clay and sandstone of the overlying Shinarump and Chinle formations in the Petrified Forest region.

A yellow uranium-bearing mineral, probably carnotite, coats fracture surfaces in the dull-colored petrified tree trunks scattered over much of the tract. Whether the mineral is secondary after a uranium mineral within the petrified wood or whether it is derived from some other source is not known. In general, the more colorful the petrified material the less radioactive it is.

Representative samples from two of the logs contained 0.007 and 0.010 percent U. The radioactivity was equivalent to 0.018 and 0.014 percent U, respectively, suggesting a significant amount of leaching.

Pima County

Black Dike deposit

The Black Dike deposit is on a group of 5 patented claims in secs. 23, 24, 25, and 26, T. 17 S., R. 10 E., on the west flank of the Sierrita Mountains about 27 miles south-southwest of Tucson. The claims are on ranch land owned by Colonel Moller of Tucson and were leased from him in 1951 by Albert Ybarra, Glen Allen, and Bryce Wilson, all of Tucson.

The lower western slope of the Sierrita Mountains in the vicinity of the Black Dike claims is intricately cut by dry washes to form a rough rolling topography with an average relief of less than 200 feet. Nearby hills and ridges, however, rise as much as 400 feet above the surrounding surface.

The deposit is developed by a shaft originally dug in search of copper, probably just before World War I. The shaft lay idle for several years and was then back-filled with waste material. Early in 1950, the remaining waste rock about the collar of the shaft was discovered to be radioactive by Ybarra. R. J. Wright of the U. S. Atomic Energy Commission made a brief examination of the property in 1950. At his suggestion the lessees commenced rehabilitation of the workings. The shaft had been cleared to a depth of about 75 feet in March 1951, but still contained an undetermined amount of back-filled rock.

In February 1951 the senior author and J. W. Adams examined the deposit. The area immediately surrounding the Black Dike shaft was mapped (fig. 6), the shaft was sketched in vertical section, and two cross sections

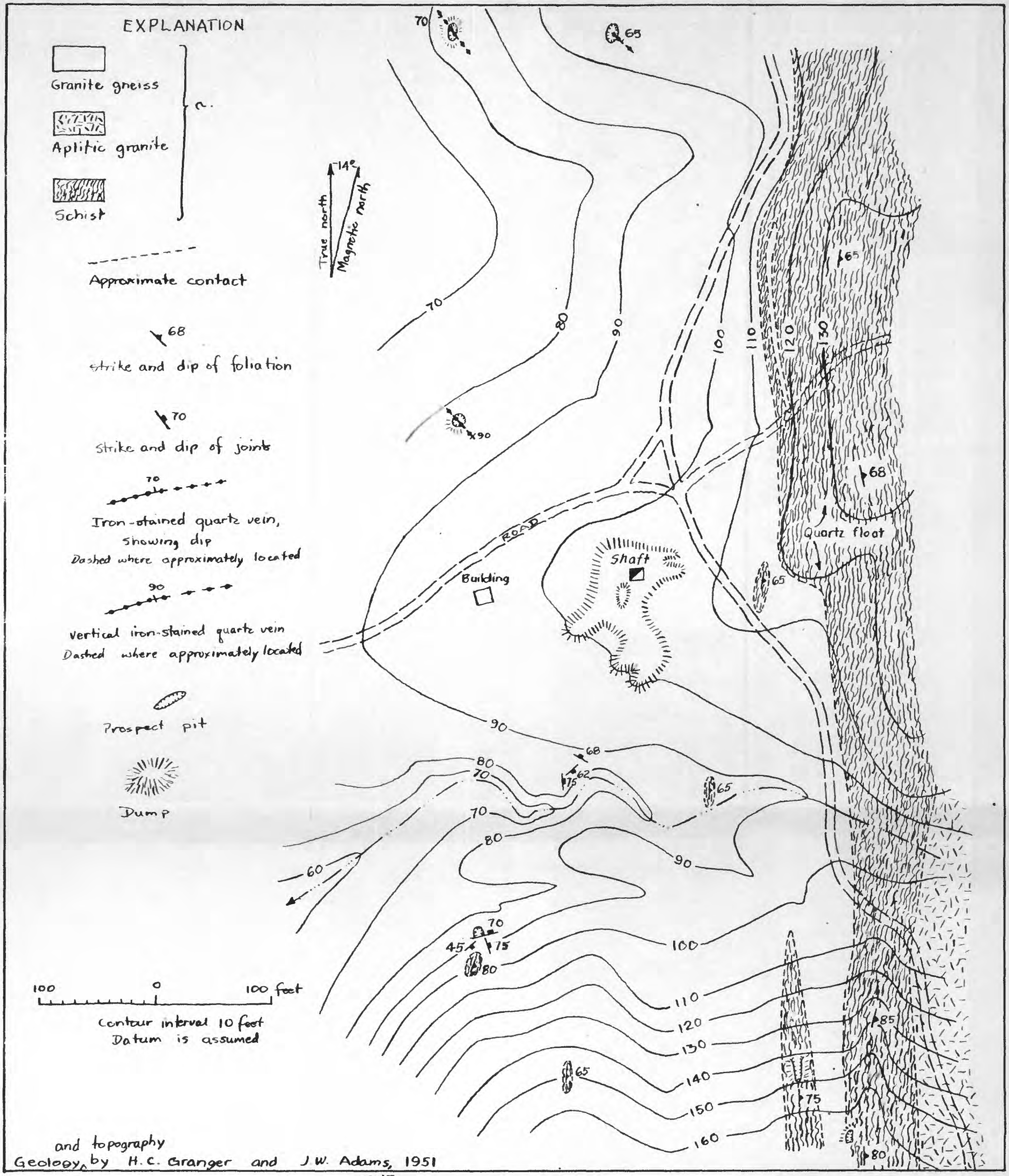

FIGURE 6.-GEOLOGY OF THE BLACK DIKE DEPOSIT, PIMA COUNTY, ARIZONA

were prepared (fig. 7). The location and uranium content of several samples collected in the mine workings are shown in figure 7.

The west flank of the Sierrita Mountains is composed of steeply dipping metamorphosed sandstone, limestone, shale, rhyolite, tuff, and conglomerate intruded by a massive granite core (Ransome, 1922). According to the Arizona state geologic map (Darton and others, 1924), these metamorphosed sediments consist largely of the Upper Paleozoic Tornado or Martin limestones, and the Comanche series of Cretaceous age. Much of the core of the mountains is composed of granite and granite gneiss. Either the granite magma invaded and partly assimilated the bedded rocks or solutions granitized them.

The Black Dike deposit is near the contact between granite and metamorphosed sedimentary rocks. The metamorphic rocks trend N. 0°-20° W. with very steep dips; the major structural and topographic features are related to this trend. The more resistant strata, such as silicified limestone, form northerly trending, discontinuous ridges. The Black Dike claims were named for a low ridge of micaceous schist that is intensely stained with iron and manganese oxides.

The mineral deposits on the west side of the Sierrita Mountains are, for the most part, in the limestones. Many of these were developed before World War I and produced unrecorded but probably small tonnages of lead, silver, and copper ores. The ore minerals are of sporadic occurrence and rarely form continuous ore bodies. Primary minerals include pyrite, chalcopyrite, argentiferous galena, sphalerite, argentite, cerargyrite, native gold, and, near the north end of the district, fluorite. Secondary

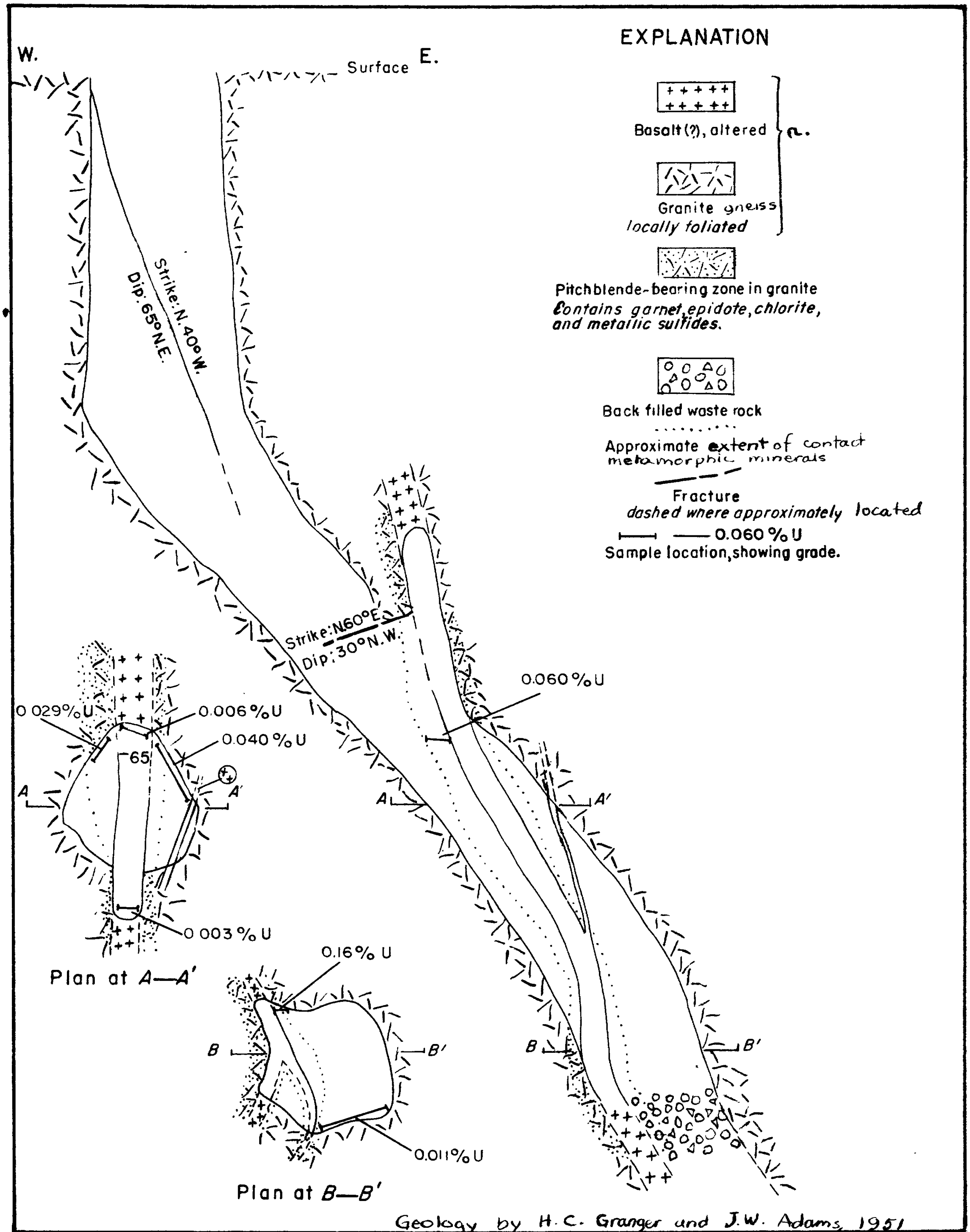

FIGURE 7.—SECTION OF THE BLACK DIKE SHAFT, PIMA COUNTY, ARIZONA.

10 0 10 Feet

minerals are common near the surface and include chalcocite, malachite, azurite, cerussite, anglesite, wulfenite, and locally psilomelane and pyrolusite. Ransome (1922) states that the metallization has not been strong and that large bodies of ore probably do not exist.

The Black Dike mine is in gneissic granite that is cut by an intensely altered mafic dike. The shaft was sunk along a copper-stained fracture zone. At about 40 feet the shaft penetrated the altered dike which it followed to the depth that rehabilitation had progressed in 1951.

The mafic dike is irregular and averages about 2 feet thick. Where observed underground it strikes about N. 10° W. and dips 65° E., roughly parallel to the local foliation. The dike is highly altered and is concealed by rubble at the surface. Microscopic examination of thin sections of this rock shows a fine-grained texture similar to basalt. The lath-shaped feldspars and ferro-magnesian phenocrysts are altered to clay and chlorite. Calcite is disseminated through the chlorite and occurs as veinlets as much as one inch wide in the dike.

A very irregular zone in the gneissic granite bordering the dike contains local concentrations of garnet, chlorite, and epidote. These minerals give the finer-grained schistose facies of the gneiss a greenstone-like appearance. Pyrite, chalcopyrite, and magnetite are associated with the contact minerals. Fine-grained purple fluorite is disseminated through the greenstone-like rock and is commonly associated with the chalcopyrite.

The garnet, chlorite, epidote, and sulfides extend outward from the dike for several feet locally, but elsewhere the dike is in contact with the normal granite gneiss. Both the hanging and footwalls of the dike have been locally mineralized.

The radioactive rocks are in the sulfide- and flourite-rich zones within the contact metamorphic rocks. The most radioactive rock is along irregular fractures coated with a black sooty material that is probably partly manganese oxide and partly pitchblende (L. Evans, U. S. Bureau of Mines, oral communication). At most this radioactive zone extends about two feet outward from the borders of the dike. The black sooty-filled fractures locally follow the contact but were not observed within the mafic dike rock.

Samples cut in the dike rock contained less than 0.006 percent uranium, whereas samples cut in the contact metamorphic rocks contained from 0.011 to 0.16 percent uranium. The samples contained from 0.01 to 0.97 percent copper, the lowest assays being in the dike rock.

Local concentrations of uranium minerals would probably be found by further exploration along the dike, but it is not likely that a large deposit of high grade uranium ore will be discovered. Ransome's (1922) statements regarding weak metallization for the district as a whole probably apply to the uranium as well as to the base metal deposits.

Since the examination of the Black Dike deposit in 1951, some further mining has been done on the property. The results of the newer work are not known by the writers.

Copper Squaw mine

The Copper Squaw mine is in sec. 36, T. 14 S., R. 2 E., approximately 2 miles east of Quijotoa. The uranium deposit is in a brecciated fault zone in altered Tertiary (?) andesite. The fault zone strikes N. 50° E., dips 30° NW., and ranges from 6 to 36 inches wide.

Mine workings on the property are a 110-foot shaft inclined 30° NW. and four prospect pits. About halfway down the shaft the fault zone is particularly wide and is well exposed in a stope. At the bottom of the shaft the fault zone is less than a foot wide.

Radioactivity in the stope is quite low, but radioactive material stockpiled near the collar indicates that uranium-bearing material has been removed from the stope. The predominant uranium minerals are uranophane and uraninite. Associated ore minerals are malachite and sparse azurite and chalcocite. Gangue minerals are quartz, calcite, hematite, and limonite.

A sample representative of the stockpile of selected material contained 0.12 percent eU_3O_8. Two selected chip samples, taken before the stope was completed, contained 0.76 percent U_3O_8 and 1.40 percent U_3O_8 respectively (Wells and Puttock, 1953).

Glen claims

The Glen claims are on the northwestern flank of the Sierrita Mountains in the NW¼ sec. 30, T. 17 S., R. 11 E., about 28 miles south-southwest of Tucson. The claims are about a mile east-southeast of the Black Dike claims and were in 1951 under lease to Albert Ybarra and Glen Allen of Tucson. The property is underlain chiefly by granite; exposures of quartz-biotite schist are apparently not extensive. The radioactive material occurs in and bordering a breccia zone that strikes N. 20° W. and dips about 80° SW. The silicified core of the breccia zone is about 6 feet wide but highly fractured rocks extend several feet on either side of the core. The length of the breccia zone was not determined, but it is radioactive for about 200 feet.

An open cut about 15 feet long, 5 feet wide, and as much as 6 feet deep exposes radioactive material along the hanging wall of the breccia zone near the northwest limit of radioactivity. Rock exposed in the cut is mostly granite, but near the face there is a narrow vertical zone of light-colored, intensely altered rock that contains a large amount of fine-grained muscovite or bleached biotite. The borders of this rock are indistinct where it merges with the granite and it is so easily weathered that it is not exposed at the surface. A 4-foot channel sample, which cuts 2 feet of the altered rock and 2 feet of granite, contained 0.015 percent U. The radioactivity of the sample was equivalent to 0.035 percent U.

Nearly 200 feet southeast of the open cut is a more highly radioactive exposure of the breccia zone. The rock is silicified and has the appearance of aplite. Iron-stain is prominent and pyrite is scattered along some of the fractures. This rock contained 0.027 percent U, but the radioactivity was equivalent to 0.080 percent U. The lack of equilibrium in the samples indicates that the outcrops on the Glen claims have undergone considerable leaching, and the uranium content of the fresh rock below the zone of intense oxidation may be greater than that at the surface.

Iris and Natalia claims

The Iris and Natalia claims are in the SW¼ sec. 26, T. 21 S., R. 11 E. in the Oro Blanco mining district. The claims were owned in 1951 by Elmer and Lester Fernstrom of Tucson and Roman Encinas of Arivaca.

Several abandoned shafts and open cuts on the property explore three roughly parallel, copper-bearing shear zones in rhyolite. Most of the mining was done on a shear zone that is several feet wide, and that strikes N. 80° E., and dips 34° N. Chalcocite nodules that also contain silver, gold, and uranium occur in gouge within the shear zone, especially along the footwall. Perhaps these chalcocite nodules are related to numerous iron-stained quartz veins that are exposed at the surface and apparently crosscut the shear zone.

Microscopic study of a specimen of radioactive material selected from the dump disclosed quartz, covellite, malachite, limonite, and a uranium mineral tentatively identified as kasolite. This specimen was reported (Wright, 1950a) to contain 0.76 percent U_3O_8. However, very little radioactive material could be found in the workings in 1951.

The owners reported that two diamond drill holes intersected the flat-dipping shear zone at about 50 feet; no radioactive material and very little copper ore were found in the drill core.

Lena No. 1 and Genie No. 1 claims

The Lena and Genie claims are in secs. 8 and 5, respectively, T. 18 S., R. 11 E., on the west flank of the Sierrita Mountains about 25 air-miles southwest of Tucson. The claims are owned by Manuel Obregon of Tucson.

On the Lena No. 1 claim, a shaft about 16 feet deep follows a radioactive fissure vein in a light-colored, slightly foliated granite. Locally the granite contains irregular xenoliths of impure quartzite and has steeply dipping banding or bedding with a northwesterly trend. This suggests that the rock may be a series of granitized quartzose sediments. Widely scattered, dark-colored, fine-grained dikes cut the granite in various directions but most commonly they trend northwest and dip to the southwest.

Fractures in the area of the Lena No. 1 claim trend northwest for the most part, and dip steeply to the southwest (fig. 8). This trend is roughly parallel to the banding in the granitized (?) rock. Along one of these fractures is a narrow vein that is traceable for about 25 feet and that contains disseminated magnetite, pyrite, chalcopyrite, galena, and sphalerite (?) in a dense quartz gangue. Kasolite (?) and sooty pitchblende coat fracture surfaces, chiefly along the footwall side of the vein. These relationships are evident only near the bottom of the shaft (fig. 9); near the surface the vein narrows to a nearly-unmineralized fracture which forms the hanging wall of a shattered zone about 3-4 feet wide. Rock in the shattered zone is altered, locally silicified, and contains sparse disseminated pyrite. Hydrous iron oxides stain the rock and green copper

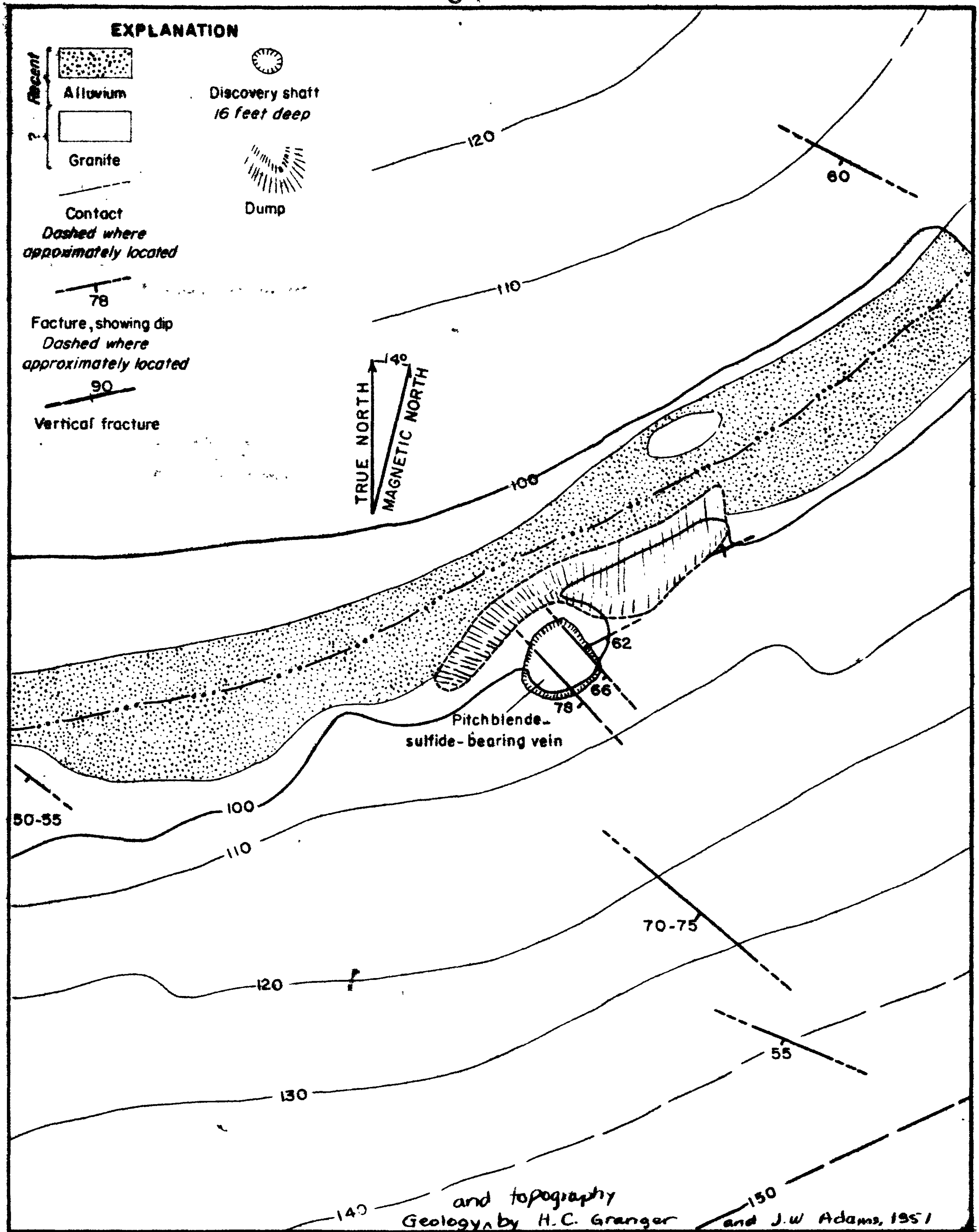

FIGURE 8.—SKETCH MAP OF THE LENA NO.1 CLAIM, PIMA COUNTY, ARIZONA, SHOWING FRACTURE PATTERN AND URANIUM-BEARING VEIN.

20 0 20 Feet

Contour interval 10 feet.
Datum is assumed

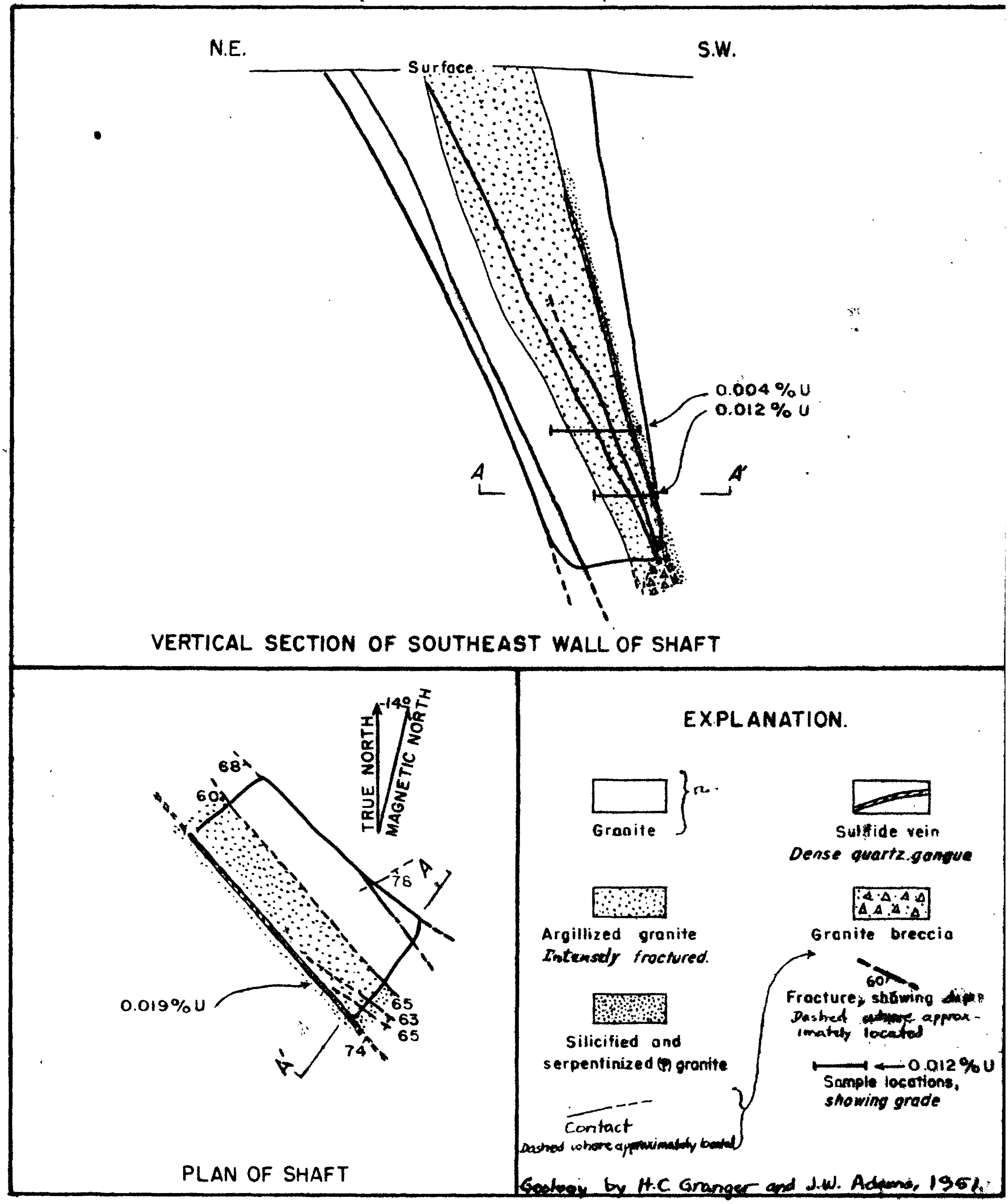

FIGURE 9.– GEOLOGY OF THE DISCOVERY SHAFT, LENA NO. 1 CLAIM, PIMA COUNTY, ARIZONA.

5 0 5 Feet

minerals are sparingly present. Alteration was most intense near the pitchblende-sulfide-bearing vein, and the hanging-wall side is greenish, possibly due to serpentine, and silicified for about 3 inches adjacent to the vein.

The vein itself is about 1 to 2 inches wide at the bottom of the shaft where the vein material is apparently a fissure filling. The relative movement between opposite walls of the vein, if any, cannot be determined, and the fracture appears to be more of a joint than a fault. Other related fractures in the immediate area are tight and apparently contain no ore minerals. For these reasons it is suggested that neither the structure nor metallization was sufficient to form a large ore body on the Lena claim.

Two channel samples were cut across the shattered zone near the bottom of the shaft; the samples contained 0.004 and 0.012 percent U. A grab sample of the vein filling contained 0.019 percent uranium. These contrast sharply with a selected sample taken by the owner which assayed over 2.0 percent U and a sample selected by Faick and Romslo (1954) from the vein filling, which contained 0.25 percent U_3O_8.

Very little anomalous radioactivity can be noted on the Genie No. 1 claim. The country rock is a light-colored granite that contains disseminated pyrite and abundant tourmaline (schorl) both as radiating clusters of crystals in the granite and as veins up to 4 feet wide which consist almost entirely of quartz and tourmaline. These veins have a general northwest trend and dip steeply to the southwest. A fracture along the southwest wall of one of these veins showed radioactivity equal to about

5 times the normal or background reading. The radioactivity, however, is not believed to be related genetically to the tourmaline.

Radioactivity is highest in the altered rock and selvage adjacent to a fracture in granite exposed along a draw that also crosses the Lena claim. The fracture strikes about N. 40° W. and is nearly vertical. No uranium or sulfide minerals were seen in the selvage zone, but a sample contained 0.004 percent U and showed radioactivity equal to 0.008 percent U.

The character of the Genie deposit is very similar to that of the Lena deposit, but the exploration has been more shallow.

Sure Fire No. 1 claim

Abnormal radioactivity was discovered in August 1949 on the Bar-LY Ranch in sec. 15, T. 13 S., R. 18 E., about 30 miles east-northeast of Tucson. The Sure Fire No. 1 claim was located on the radioactive material by Dominick Oberto and others of Tucson. Four shallow prospect pits were sunk on the property prior to renewed activity in 1954.

Rocks on the Sure Fire No. 1 claim are believed to be Precambrian and Cambrian in age. The oldest rocks consist of granitic gneiss and gray-green schist. The schist is composed primarily of quartz and chlorite interlaminated with thin layers of dark minerals. Foliation in the schist trends northwest and dips 25°-55° NE. This rock may belong to the Pinal schist of Precambrian age. The granite gneiss is apparently intrusive into and nearly concordant with the foliation of the schist; the granite gneiss is very likely related to the Oracle granite which is described (Moore, Tolman, and others, 1949) as a coarse-grained, nearly white rock with large feldspar phenocrysts locally crushed and containing schlieren. The gneiss and schist are overlain on the ridges by Bolsa (?) quartzite which is in turn overlain by the Abrigo (?) limestone, both of Cambrian age. Fine-grained dark-colored dikes cut the Precambrian rocks locally and cut later rocks in nearby areas. The dikes are difficult to trace on the surface, but where exposed they show both concordant and discordant relationships to the gneiss and schist.

The four shallow prospect cuts on the Sure Fire No. 1 claim will be designated as Pits A, B, C, and D; all are along a generally north-trending arroyo which carries water only during heavy rains. Pit A, about 30 feet above the floor on the east side of the arroyo, exposes weakly radioactive altered and iron-stained schist that contains a few random veinlets of purple fluorite. A 14-foot chip sample of the schist just below Pit A contained 0.002 percent U, although the radioactivity of the sample was equal to 0.006 percent U.

Pit B, an open cut on the east wall of the arroyo about 60 feet northwest of Pit A, exposes a bed of gray, platy, quartzose schist that is radioactive. The radioactive material is locally crushed and altered and contains very small veinlets of quartz, fluorite, and calcite. Above the exposed bed the schist is dull gray-green, soft, and apparently chloritic. The abnormal radioactivity seems to be continuous but very weak between Pits A and B.

Across the arroyo from Pits A and B is a small area of weakly radioactive schist that has not been explored by the owners. The radioactivity is largely in float; little bedrock can be seen.

Pit C is in an 8-foot wide crushed and fractured zone in altered gneiss north-northwesterly from Pit B. (This is believed to be the site of the Blue Rock shaft, sunk after the authors' examination.) The gneiss contains veinlets and breccia fillings of quartz, calcite, purple fluorite, and a white, unidentified clay-like material. Some of the fractures contain yellow uranium minerals identified as uranophane and autunite by the U. S. Bureau of Mines in Tucson. The crushed gneiss is iron-stained; pyrite and chalcocite are disseminated through the slightly altered rock near the margins of the crushed zone. No continuity of trend of the radioactive material is apparent. A four-foot channel sample across the middle of the crushed zone showed radioactivity equivalent to 0.13 percent U but contained only 0.008 percent U by chemical assay.

Pit D is about 170 feet north of Pit C. It is in fractured schist along the west side of the arroyo. The two most prominent fractures strike N. 85° E. and N. 60° W., and dip 80° N. and 75° NE. respectively. They are about 4 feet apart in the face of the pit. Purple fluorite fills veinlets between the fractures. A dull black coating on fracture surfaces is the most radioactive material, but no uranium mineral has been identified. The material is out of equilibrium; two channel samples that contained only 0.004 and 0.006 percent U had an equivalent uranium content of 0.069 and 0.038 percent, respectively.

None of the radioactive zones has distinct continuity although they are apparently longest parallel to the foliation. A zone of weak radioactivity is traceable between Pits A and B, but Pit C and Pit D seem to be in separate radioactive zones less than 25 feet in length. The radioactive zones all have been intensely leached of uranium inasmuch as the uranium is not in equilibrium with its daughter products. All the zones contain minor amounts of purple fluorite, although the fluorite itself is not abnormally radioactive.

Van Hill No. 5 claim

The Van Hill No. 5 claim is on the northeast flank of the Rincon Mountains in sec. 15, T. 13 S., R. 18 E., about 30 miles east-northeast of Tucson; the claim was owned in 1951 by R. M. Vanover and others of Tucson.

Radioactive material is found in an altered quartzite underlain by Precambrian metamorphic rocks and overlain by Paleozoic limestone. The quartzite, probably of Cambrian age, is cut by a radioactive fracture zone about 4 feet wide and traceable for about 50 feet; radioactivity is most intense where the fracture zone is exposed in an arroyo. Here the quartzite is iron- and manganese-stained and is apparently impregnated with fine-grained ferromagnesian minerals. According to the owner, a prospect pit that was excavated in the bottom of the arroyo was almost completely filled with sand and gravel at the time of the examination. A yellow uranium mineral, probably autunite, is associated with purple fluorite in the fractures a few feet below the surface.

The deposit has been severely leached at the surface; analysis of a grab sample indicated that the uranium is not in equilibrium. The sample contained 0.008 percent U whereas it contained 0.17 percent eU. If the apparent lack of equilibrium is the result of leaching, the grade of the uranium may improve with depth.

Van Hill Nos. 7 and 8 claims

The Van Hill Nos. 7 and 8 claims include a radioactive limestone deposit in the NW¼ sec. 24, T. 13 S., R. 18 E. about 30 miles east of Tucson and 1.5 miles south-southwest of the Bar-LY ranch house. (See U. S. Geol. Survey Redington quadrangle topo. map, 1943.) The Van Hill No. 7 claim was located by R. M. Vanover and the Van Hill No. 8 claim was located by L. D. Hill, both of Tucson.

The uranium deposit is in a series of generally thin-bedded limestone, shale, and conglomerate strata that strike N. 40°-60° W. and dip 45°-70° NE. The rocks are probably upper Paleozoic in age and may belong to the Naco limestone, which is of Pennsylvanian age. The radioactive zone, exposed just below the crest of a short ridge formed by a resistant limestone bed, follows a petroliferous limestone bed as much as 2 feet thick (fig. 10). Radioactivity commonly extends into the overlying fine-grained limestone and the underlying iron-stained shaly limestone. Maximum thickness of the radioactive rock is about 6 feet. It occurs as two segments 115 and 190 feet long separated by 28 feet of nonradioactive limestone. The northwest segment apparently is slightly higher stratigraphically than the southeast segment, possibly because of the lenticular nature of the bedding.

Three samples were taken across the radioactive zone. The uranium content ranged from 0.011 to 0.021 percent and is not far out of equilibrium, which suggests that the limestone has not been appreciably leached. No uranium minerals were recognized but field evidence indicates that the petroliferous material is the most radioactive.

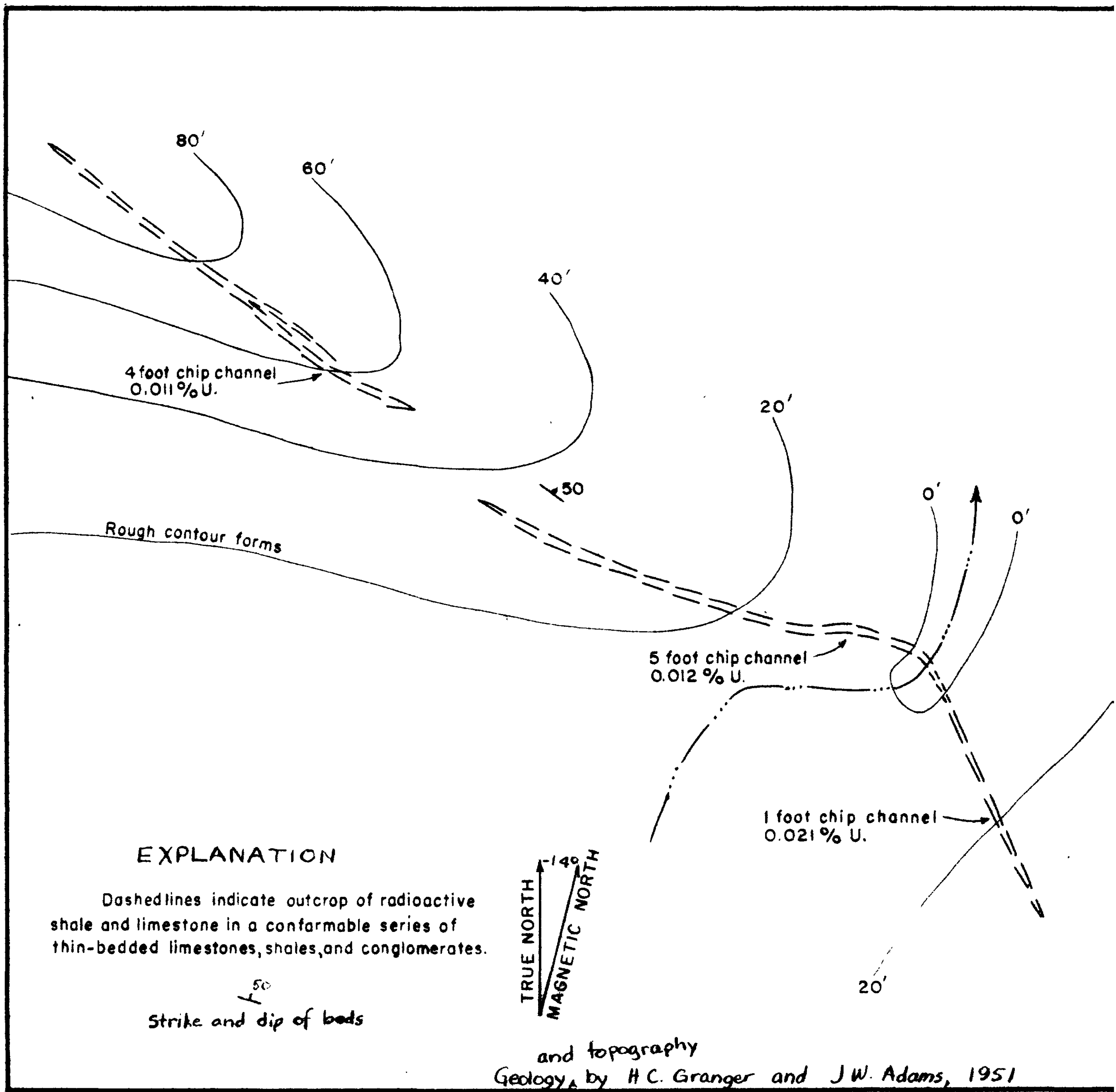

FIGURE 10.–DIAGRAM OUTLINING RADIOACTIVE ROCKS ON THE VAN HILL NOS. 7 AND 8 CLAIMS, PIMA COUNTY, ARIZONA.

40 0 40 Feet

Datum is assumed

Pinal County

Honey Bee No. 4 claim

The Honey Bee No. 4 claim is about 2 miles southwest of Kelvin in sec. 16, T. 4 S., R. 13 E. The claim was owned in 1951 by Leo Wall of Ray and I. D. Hollenbeck of Kelvin. The claim was originally worked for copper but the copper deposits are nonradioactive. Radioactivity is associated with a shattered fine-grained mafic dike about 4 feet wide and a nearby porphyry dike, each cutting the granite country rock. The petrographic classification of these dikes was not determined.

About 2 feet of rock along the hanging wall of the mafic dike is locally radioactive for nearly 200 yards. The radioactive material is intensely iron stained and may contain copper although none was noted. A selected grab sample contained 0.021 percent U; the average uranium content is probably even lower.

The porphyry dike is radioactive in spots for about 200 feet, one spot indicated radioactivity of 0.4 mr/hr on a portable field Geiger counter. The normal background was about 0.04 mr/hr. The dike is iron stained, and uranium may be associated with the iron oxides.

Shorty claims

The Shorty Nos. 1, 2, and 4 claims are in sec. 15, T. 4 S., R. 13 E., about 3 miles southwest of Kelvin. They were owned in 1951 by Leo Wall and Ray Adams of Ray, and I. D. Hollenbeck of Kelvin. The country rock on the Shorty claims is a coarse-grained, locally-porphyritic granite. The radioactive material is associated with quartz stringers and iron and manganese oxides in broad shear zones; the wall rocks commonly show argillic alteration products. The shear zones range from about 3 feet to 100 feet wide and are traceable for several hundred yards, but the radioactivity is spotty. On the Nos. 1 and 2 claims the zones strike N. 55°–85° W. and are nearly vertical; on the No. 4 claim they strike N. 45° W. and dip 65° NE. The radioactive parts of the shear zones are explored by several prospect pits and one short adit about 15 feet long.

No samples were taken, but the radioactivity was about 2 to 5 times the normal background reading. This is probably equivalent to less than 0.01 percent U.

Wooley No. 1 claim

The Wooley No. 1 claim is about 5 miles southwest of Kelvin in sec. 33, T. 4 S., R. 13 E. and was owned in 1951 by Leo Wall of Ray and I. D. Hollenbeck of Kelvin. The Wooley No. 1 claim was originally explored for copper by a 250-foot shaft. An unknown tonnage has been mined, largely from a resistant, quartz-filled breccia zone that contains malachite, chalcopyrite, and chalcocite (?). This material is essentially nonradioactive.

At least three veins and shears cutting the coarse- to fine-grained granite on the claim are, however, radioactive. The three veins are exposed within 150 yards of each other along a draw below the copper workings. They are sub-parallel and strike N. 63°–85° E. and dip 70°–90° SE. For convenience the veins will be known as Nos. 1, 2, and 3. Vein No. 1 is less than one inch wide but is bordered by a zone as much as 3 feet wide characterized by argillic alteration products, minor silicified rock, and iron stains. The vein is slightly copper stained. Radioactivity is 2 times the normal background.

Vein No. 2 is one-eighth to 3 inches wide, contains chrysocolla, and is 2 to 3 times more radioactive than the normal background. Vein No. 3 is developed by a 100-foot adit along a shear zone made up of a series of fractures and stringers 3 to 4 feet apart. The rock in the shear zone commonly is copper stained. A high-grade sample from the adit contained 0.017 percent uranium.

Santa Cruz County

Annie Laurie claims

The Annie Laurie claims include a lead-zinc-uranium prospect in the SW¼ sec. 8, T. 23 S., R. 11 E., about 25 miles west of Nogales and 3 miles south of the nearly-abandoned mining town of Ruby. The claims were owned in 1951 by J. H. Bright, Jr., of Tucson. Radioactivity was discovered on the Annie Laurie prospect (fig. 11) in the summer of 1949 when Bright tested a calcareous tufa spring deposit with a Geiger counter (Wright, 1951). A small excavation, Pit F, failed to reveal any uranium minerals. Further prospecting on the hillside above the tufa disclosed two abnormally radioactive areas. Pit C contained some secondary uranium minerals; Pit A exposed pitchblende and metallic sulfides in a carbonate gangue. Other shallow prospect pits were dug but they were barren, except for Pit B,

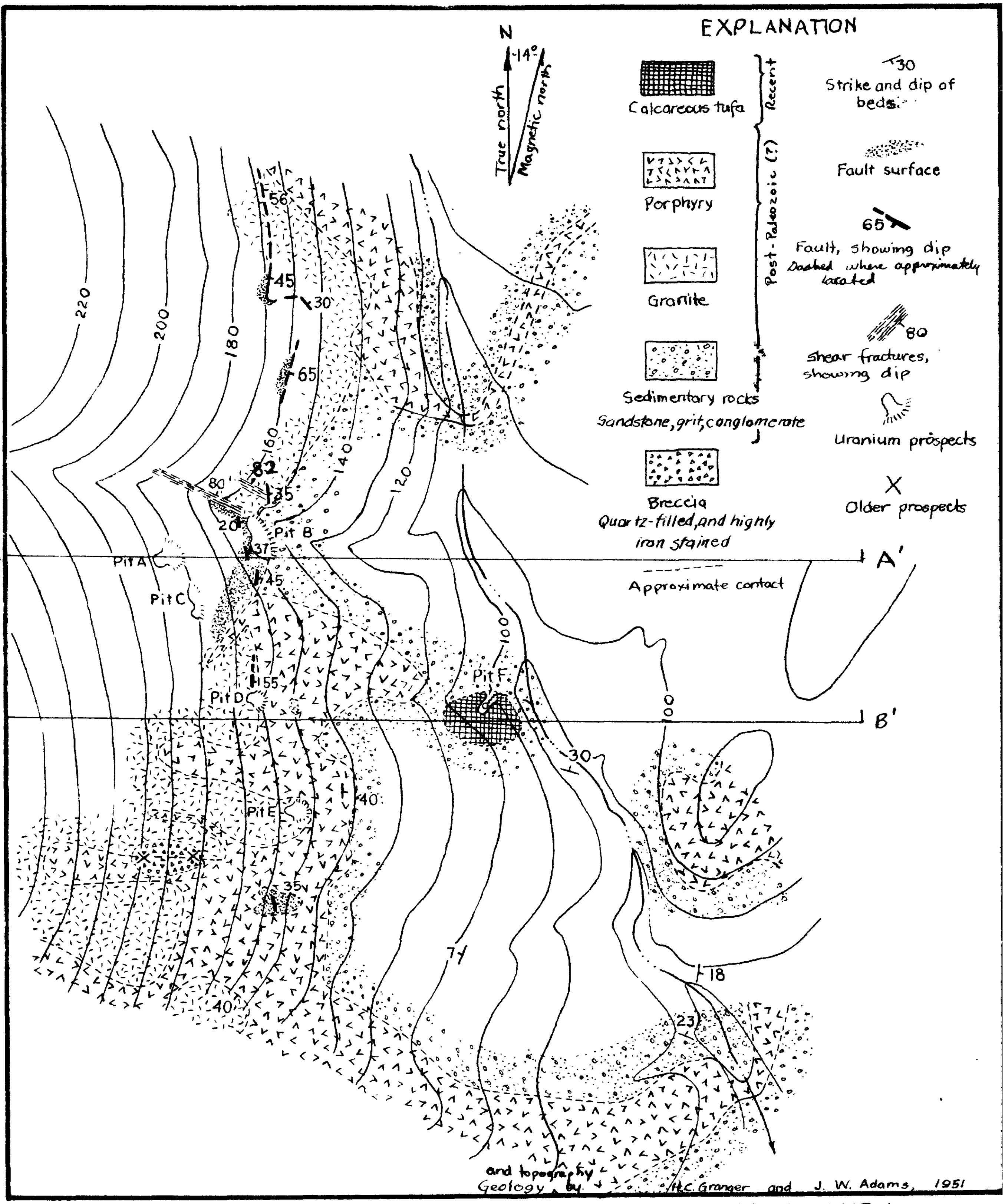

FIGURE 11.–GEOLOGIC MAP OF THE ANNIE LAURIE PROSPECT, RUBY DISTRICT, SANTA CRUZ COUNTY, ARIZONA.

100 0 100 feet

Contour interval 10 feet

Datum is assumed

which exposed minor amounts of sulfides in a carbonate gangue. Information about a 100-foot hole diamond drilled in 1952 is not available, as the core was scattered about the drill site and was not logged (Rambosek and Miller, 1953).

The uranium deposits on the Annie Laurie claim are in fine-grained granite which intruded a series of sedimentary rocks. The contact between the granite and sedimentary rocks is locally intruded by a porphyritic rock, which also forms dikes and sills cutting the sediments. The ages of these rocks are not known but they are probably post-Paleozoic.

The sedimentary rocks consist of interbedded shale, limestone, grit, and conglomerate. They are all limy but were probably deposited under fresh water. Although they are essentially flat-lying, the sedimentary rocks are tilted and jumbled near igneous intrusions. The dips may change over 20° in 100 feet under these conditions.

A fine-grained granite, host rock to the uranium deposits (fig. 11A), is in contact with the sedimentary rocks on the Annie Laurie claim. The granite has intruded the sedimentary rocks as a stock of unknown proportions. Because of the normally white to red orthoclase, the granite is white or pinkish, except near the mineral deposits where the feldspar is altered and assumes a greenish caste.

A porphyritic rock, probably andesite, forms an irregular dike that follows the contact locally between the granite and sedimentary rocks. The porphyry forms dikes and sills in the sediments and uneven lobes extending short distances into the granite. The uranium deposit is in the granite close to the contact with porphyry.

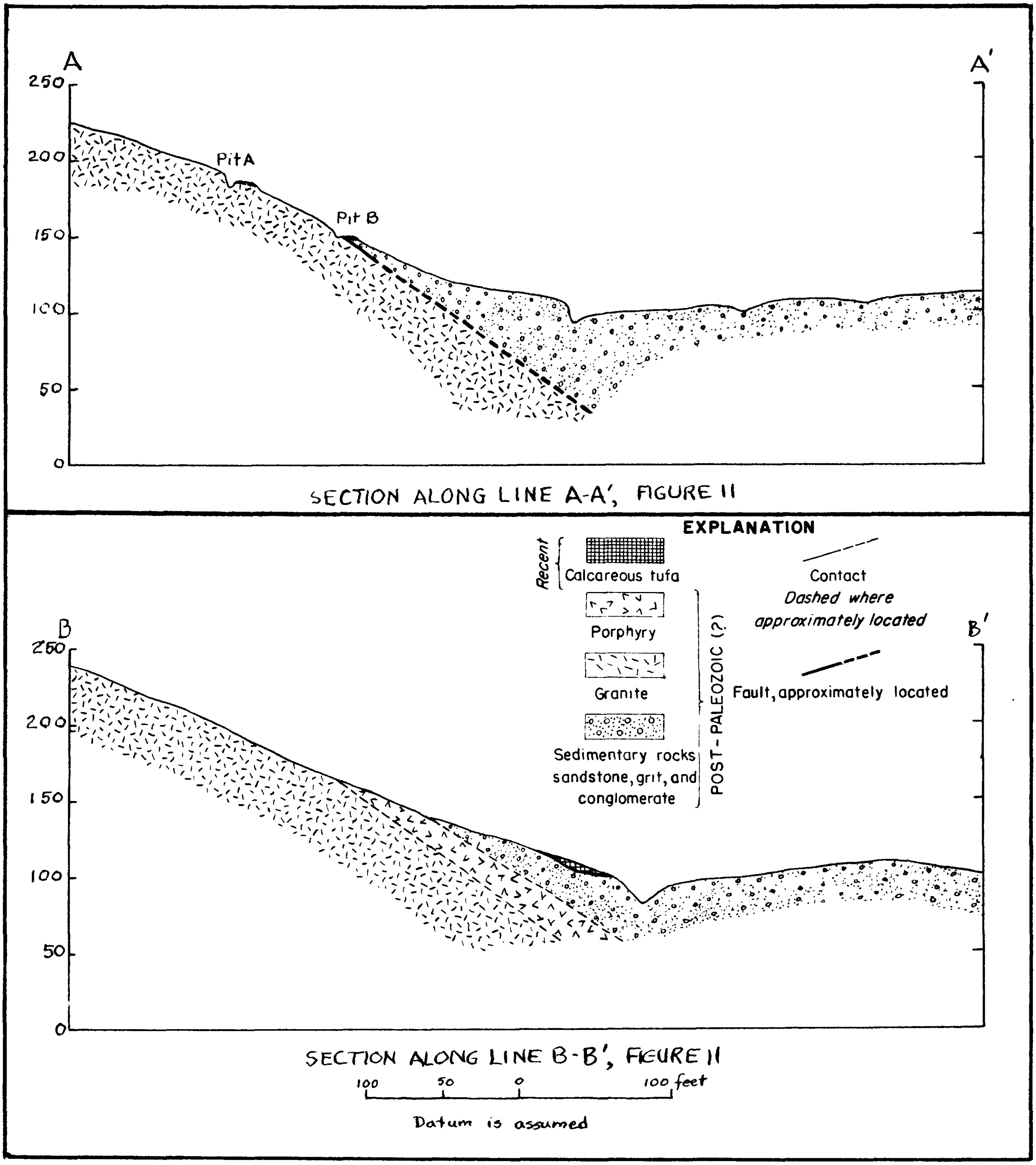

FIGURE 11A.- GEOLOGIC SECTIONS, ANNIE LAURIE PROSPECT, RUBY DISTRICT, SANTA CRUZ COUNTY, ARIZONA.

A system of north-trending east-dipping faults is believed to be the most significant feature related to the localization of the uranium. These faults roughly parallel the margin of the granite and are nearly parallel to the slope of the hillside; in fact, many square feet of fault surface are exposed near Pit B. Several of these faults are filled with breccia cemented with porous quartz. The pore spaces in the quartz are believed to have once contained calcite which has since been removed by weathering. Irregular zones composed of silicified breccia are exposed in the granite within the faulted zone. The faults were later than intrusion of the porphyritic rock but tend to cut the granite more than the porphyry. Locally, however, the porphyry is in fault contact with the granite.

North of Pits A and B is a well-defined zone of shear fractures that strikes N. 60° W. and dips steeply to the northeast. Other fractures with similar trend are common near the deposits but do not form such prominent shear zones. Locally they are limonite-filled where exposed in the pits.

Alteration in the area of the uranium deposits was characterized by weak to strong silicification and green coloration of the feldspar in the granite. Intense silicification commonly obscured the texture so that the granite is nearly indistinguishable from the porphyry. The spatial distribution of silicified rock and altered feldspar relative to the uranium-sulfide-carbonate deposit suggests that there is a close relationship between the two.

The veins that contain the ore minerals range from a knife-edge to 3 or 4 inches in thickness, are irregularly shaped, and are seldom over

3 to 4 feet long. Sulfides and carbonates occur in these veins near the north-trending faults. No ore minerals were seen in the faults although the quartz-carbonate breccia filling suggests that the veins and the faults are genetically related. The walls of the veins generally have been replaced by the carbonate and silica. Minor amounts of carbonate may extend several inches into the altered wall rocks. Sphalerite, galena, chalcopyrite, pyrite, and purple fluorite occur as blebs and stringers in the carbonate gangue. Pyrite is also commonly disseminated in the wall rock,

Samples at Pits A, B, and C contained 0.010, 0.015, and 0.010 percent U respectively. Two samples taken at Pit F contained 0.015 and 0.010 percent U nearly in equilibrium with its daughter products. The first sample from Pit F consisted of a calcareous tufa and the second of pyrite-rich sedimentary rocks. Wright (1951) lists assays as high as 0.79 percent uranium but these were reportedly from selected samples.

Field relations suggest that the pitchblende and sulfides were deposited by hydrothermal solutions that circulated along the north-trending, eastward-dipping faults and fractures. Apparently, however, only silica and carbonates were deposited directly in the faults; ore minerals were precipitated in and near related fractures bordering the faults. If pitchblende and sulfides were deposited in the faults, they may have been removed from the near-surface parts of the faults by leaching. In this case, ore minerals might be found by further exploration below the zone of weathering. Leaching of the deposits and movement of groundwaters along the N. 60° W. set of fractures has probably resulted in the calcareous tufa deposit at Pit F.

An article by Anderson and Kurtz (1955) describing a biogeochemical reconnaissance of the Annie Laurie prospect was published after this paper was written.

White Oak property

The White Oak property is in the NE¼ sec. 2, T. 24 S., R. 12 E., 15 miles northwest of Nogales. Host rock for the deposit is either rhyolite porphyry or possibly welded tuff of Cretaceous or Tertiary age. The deposit is in a mineralized shear zone from which oxidized lead ore was mined.

Mine workings, all of which follow or intersect the shear zone, consist of the White Oak adit, the White Oak No. 1 adit, four smaller adits, and several surface cuts and pits. The drift entered by the White Oak adit has been stoped for almost its entire explorable length; about 350 feet from the portal the adit has been blocked by caved material. A shallow winze has been dug in search of radioactive material at the intersection of the shear zone and the White Oak No. 1 adit. Other raises and winzes in the mine connect the various workings.

The mineralized shear zone on the White Oak property has an average strike of N. 55° E. and an average dip of 80° SE. The dip ranges from 70° SE. to vertical. The few surface exposures and the mine workings indicate that the shear zone extends for at least 1,500 feet across the property. The shear is a complex zone as much as 30 feet wide, with as much as 3 feet of breccia and gouge near its center. Cerussite, the mineral originally sought by the owners of the property, occurs as fissure fillings and replacements of the breccia fragments and gouge.

The uranium minerals found on the White Oak property are in the White Oak No. 1 adit, principally at the intersection of the adit and the shear zone. The greatest concentration of uranium minerals occurs in the shear zone in two narrow intersecting fracture zones that are as much as 10 inches wide. The shear zone between the high-grade concentrations is essentially barren of uranium minerals. The most abundant uranium minerals are kasolite and uranophane; smaller amounts of dumontite, autunite, and uranium-bearing pyromorphite (?) are present. These dark-yellow and orange minerals commonly occur as earthy or hard-surfaced incrustations on fracture planes.

Material selected from the uranium-bearing fractures in the White Oak No. 1 adit contained as much as 0.82 percent U and a chip sample across a 10-inch fracture zone contained 0.47 percent U. Concentrations of such "high-grade" material are, however, small and discontinuous.

Yavapai County

Abe Lincoln mine

The Abe Lincoln mine is in the SW$\frac{1}{4}$ sec. 11, T. 8 N., R. 3 W., about 14 miles by road northeast of Wickenburg. A limited partnership known as "The Abe Lincoln Mines" owned the property in 1952. A small amount of copper ore has been produced from the Abe Lincoln vein system since the mine's inception prior to 1917.

Principal mine workings are two vertical shafts and two adits that connect with 3,150 feet of drifts and crosscuts. Although both shafts are inaccessible because of caved rock and water, Elsing and Faick (1952) report that mine records show one shaft was sunk 660 feet and gave access to workings on the 145-, 175-, 350-, and 660-foot levels whereas the other shaft was sunk 175 feet to connect to the 350-foot level of the mine. One adit follows the Abe Lincoln vein system on the 175-foot level for 350 feet beyond which point this drift is blocked by caved rock. The other main adit crosscuts to the drift on the 145-foot level, but the adit is partly caved at the portal and is completely blocked 160 feet in from the portal.

The country rock is a gneiss-schist complex of Precambrian age, locally intruded by Precambrian tourmaline granite and by later dikes of both felsic and mafic composition. As reflected by the strikes of the dikes, the predominant structural trends in the vicinity of the mine are N. 50° E. and N. 32°-45° W. Dikes intruded both the metamorphic rock complex and the granite.

The Abe Lincoln vein system consists of two veins separated by a narrow basalt dike; the system is on the hanging wall side of a trachite porphyry dike. The vein system, the basalt dike, and the trachite porphyry dike occupy a fault zone that strikes approximately N. 50° E. and dips 78°-89° NW. The vein on the footwall of the basalt dike ranges in width from a few inches to 5 feet; the hanging wall vein is narrower. Slickensided gouge, from 1 to 18 inches thick, is common between the basalt dike and the footwall vein. The dikes are pre-ore.

The veins consist chiefly of chalcopyrite and lesser amounts of azurite, chalcocite, and malachite in a gangue of quartz, calcite, pyrite, and limonite. Purple fluorite associated with calcite is locally present in dump material.

No radioactive material was found in place in the 510 feet of accessible mine workings but uranium minerals were found in sparse amounts on the dumps of the 660-foot shaft and the 145-level adit. Selected samples from the dumps contained as much as 0.46 percent U. The material from the shaft dump included specimens of trachite porphyry that contained fractures coated with malachite, limonite, and secondary uranium minerals, and specimens of vein material consisting of chalcopyrite, malachite, secondary uranium minerals, and fluorite in a gangue of pyrite, quartz, calcite, sanidine (?), and black matter which is possibly altered gouge. The material from the adit dump included a large specimen of banded vein material consisting of quartz, black altered gouge, sanidine (?), pyrite, chalcopyrite, and secondary uranium minerals. The principal secondary uranium mineral in this specimen was identified by X-ray methods as schoepite. It occurred as rims around pyrite grains.

Although no primary uranium minerals were identified, the presence of uraninite is suggested by the secondary uranium minerals, principally schoepite which is an alteration product of uraninite in the Belgian Congo (Palache, Berman, and Frondel, 1944, p. 628) and at Beryl Mountain, New Hampshire (Rabbitt, 1953). Finely divided uraninite may be present in the black altered gouge which is weakly radioactive in many specimens from the dumps. The altered gouge contains disseminated grains of pyrite and chalcopyrite in a fine-grained aggregate of chlorite, sericite, altered feldspar, quartz, apatite, and leucoxene (?).

Inasmuch as no significant radioactivity was detected in the accessible mine workings, the source of the radioactive material on the dumps could not be determined. The radioactive material on the dump does not appear to be typical of the vein material from the Abe Lincoln vein system. The presence of fluorite in calcite gangue is the most noticeably different feature of much of the radioactive material. It is suggested that the uranium-bearing rock on the dumps came either from local fluorine-rich pockets in the Abe Lincoln vein system or from a separate vein away from or intersecting the main system.

Samples from a vein on a property about one mile west of the Abe Lincoln mine contained 0.006 and 0.012 percent U. Another sample that contained 0.012 percent U was taken from an exposure of the metamorphic rock complex in a road cut a little less than one mile west of the Abe Lincoln mine. Although these samples do not in themselves contain much uranium, they indicate that the area around the Abe Lincoln mine may contain significant occurrences of uranium.

Cuba and Independence claims

The Cuba and Independence claims are in T. 11 N., R. 5 W., approximately 7 airline miles north-northwest of Yarnell. On the Cuba claim, an 18-inch quartz vein strikes N. 52° W. and dips 25° NE. in a coarse-grained buff-colored granite. The mine workings consist of a 125-foot inclined shaft that connects with a 150-foot adit drift. For about 25 feet along the drift flecks of torbernite (?) occur sparingly in a narrow zone on the footwall side of the quartz vein. A chip sample across this zone contained 0.009 percent U.

On the Independence claim a thin coating of uranophane (?) was found on an exfoliation plane in the coarse-grained granite country rock. A selected sample of the material contained 0.016 percent U. The country rock in the vicinity is abnormally radioactive although not uniformly so. As measured with a scintillation survey meter background radioactivity was 0.015-0.020 mr/hr and radioactivity of the granite ranged from 0.035 to 0.140 mr/hr. The highest reading was obtained from the above-mentioned exfoliation plane; the average reading was 0.040-0.050 mr/hr. A representative sample of the granite contained 0.004 percent eU.

Kitten No. 1 claim

The Kitten No. 1 claim is in the SW¼ sec. 27, T. 15 N., R. 9 W., about 155 feet west of the Hillside mine road 4.3 miles from Bagdad. It was owned in 1951 by W. D. Moore of Bagdad. The coarse, porphyritic, Precambrian granite country rock in the area is cut by many narrow pegmatite and aplite dikes. Most of the dikes are roughly parallel to the most prominent joints which strike N. 23° W. and dip 85° NE. Development in 1951 consisted only of a shallow prospect pit.

The uranium deposit follows a fracture that crosses the regional structural trend. It strikes N. 88° W., dips 60° N. and forms a well-defined footwall for the deposit. Metatorbernite, pyrite, and fluorite are disseminated in an intensely altered zone 3-4 feet wide.

Within the altered zone most of the feldspars are changed to clay but most of the biotite retains its original form and luster. Much of the altered material and minor fractures bordering the hanging wall are intensely iron stained.

The length of the deposit at the surface is only about 15 feet and it is probably of shallow depth. The footwall fracture is traceable for about 50 feet by a narrow quartz filling and limonite stain. Several nearby fractures have the same attitude and contain minor amounts of quartz and limonite but they are not radioactive.

Two channel samples across the most radioactive part of the deposit contained 0.094 and 0.013 percent U. The first sample was apparently strongly leached; its radioactivity was equivalent to 0.20 percent U.

The significance of this deposit relative to other uranium deposits in the area is not known. It is about 3 miles from the Hillside mine occurrence but there is no reason to believe that they are related.

Peeples Valley mine

The Peeples Valley mine is in the Weaver Mountains, about 20 air-line miles southwest of Prescott. The deposit is in an elliptically shaped quartz-feldspar pegmatite in coarse-grained granite. The pegmatite strikes approximately N. 40° E. and dips from 70° NW. to nearly vertical. In outcrop, the pegmatite is about 300 feet long and 150 feet wide.

In 1953 a small amount of scrap mica was being produced from the 20-foot shaft and several open cuts that constitute the Peeples Valley mine. Other than the prevalent, although small, books of muscovite, small quantities of beryl and columbite-tantalite (?) minerals are present in the quartz-feldspar gangue. The presence of uranium and thorium is indicated by sample assays but no primary radioactive minerals were identified. The uranium occurs in yellow secondary minerals and possibly in columbite-tantalite minerals. The predominant secondary uranium mineral is uranophane.

Three samples obtained from concentrations of radioactive material contained from 0.004 to 0.13 percent U and from 0.032 to 0.078 percent Th. A selected sample from the most radioactive spot in the mine contained the most uranium and also the most thorium. The concentrations of radioactive material in the mine are few and small. Between these concentrations the pegmatite is essentially barren of uranium and thorium minerals.

Yuma County

Atom claims

The Atom Nos. 1, 2, and 3 claims were located for uranium by Richard Peters of Yuma in the fall of 1948. They are near the intersection of the U. S. Coast and Geodetic Survey coordinates 1099100 N. and 83900 E. as shown on the Picacho 15 minute quadrangle.

The country rock is medium-grained, foliated, Precambrian granite containing mica schist inclusions as much as several hundred feet long. The regional foliation strikes about N. 55° W. and dips 55° SW., but shows large local variations. A set of shear (?) joints trends N. 15° W. with a steep eastward dip. The schist inclusions commonly have a hematite vein along the footwall contact. Rarely these veins may be very weakly radioactive. Barren quartz veins occur in small swarms and locally follow the joint sets.

A 25-foot inclined shaft on the Atom No. 1 claim follows the foliation, which locally strikes N. 40°-45° W. and dips 40°-60° SW. The shaft was sunk in fractured rock that is apparently a schist inclusion partly assimilated by the enclosing granite. Along the foliation are stringers of quartz, hematite, and calcite. Weak radioactivity is probably associated with the hematite.

Other radioactive zones on the Atom claims are explored by shallow prospect pits. The radioactivity is commonly associated with hematite-rich stringers that follow either the foliation in schist inclusions, or the regional joint pattern.

Samples taken by the owner contained 0.01 to 0.04 percent U. Inasmuch as the samples indicate that the uranium is in equilibrium, it is improbable that the deposits will show an improvement in grade with greater depth.

McMillan prospect

The McMillan prospect is on the northwest flank of the Cabeza Prieta Mountains, 25.5 miles southwest of Wellton on the road between Wellton and Tule Tank. The deposit is in a fracture zone that strikes N. 34° W. and dips 68° SW. in biotite granite. Adjacent to the fracture zone is a quartz-feldspar pegmatite dike that roughly parallels the zone on the hanging wall side. The zone is traceable for 210 feet up a 30° slope and on the ridge crest. Two adits and an open cut have been driven into the fracture zone and are separated by intervals of 90 and 110 feet, respectively. The lower adit is about 10 feet long, the upper adit is about

20 feet long, and the open cut is about 5 feet long. At the lower adit stringers of pegmatite are about 2 feet above the hanging wall of the fracture zone. These stringers merge upward into a pegmatite dike 4-5 feet wide. The distance between the zone and the pegmatite gradually decreases upward until, at the upper adit and continuing upward to the open cut, the pegmatite forms the hanging wall of the zone. The fracture zone at the lower adit is about $1\frac{1}{2}$ feet wide and decreases in width upward. At the open cut near the top of the slope the width of the zone is about $2\frac{1}{2}$ inches.

Where exposed in the lower adit, the zone is stained along the fracture planes by copper and iron minerals. Along major fractures malachite and chrysocolla seams are present. The occurrence of chrysocolla and malachite at the upper adit and the open cut are similar, but the copper and iron stains are stronger than in the lower adit. The pegmatite is fractured and copper- and iron-stained where exposed in the open cut, but not in the two adits. Apparently the metallizing solutions followed the fracture zone and are not related genetically to the pegmatite.

A 50-foot vertical shaft, which does not seem to be on the fracture zone, is a short distance northwest of the adits. It is in highly fractured and iron-stained granite. Secondary copper minerals coat the larger fractures.

Radioactivity in the mine workings and on the dumps is as much as five times the background radioactivity. A stockpile of material presumably mined from one of the adits gave readings of nearly 0.5 mr/hr on a scintillation meter. A sample selected from this stockpile of copper-stained material contained 0.034 percent U; the copper content of the sample was 7.69 percent. Although it is possible that local concentrations or uranium minerals of ore grade are present, most of the rock on the McMillan property is below commercial grade.

CONCLUSIONS AND SUGGESTIONS

Some of the deposits described in this report should, in the writers' opinion, receive more detailed geologic and exploratory examinations. This has been done in the case of the Dripping Spring deposits. Other properties believed to warrant further study are the Orphan claim and Hack's mine as a coordinated investigation, the Abe Lincoln mine, and the Annie Laurie claims. Since completion of the work on which this report is based, some exploratory work has been conducted on the Annie Laurie and Orphan claims.

A coordinated study of the Orphan and Hack's claims might well disclose data that would be of use in locating and evaluating other deposits of this type. The geologic setting of these deposits is believed to be too similar to be fortuitous and it is believed to be likely that there are more as yet undiscovered or unrecognized deposits of this type on the Plateau.

The source of the uranium-bearing rock on the dumps of the Abe Lincoln mine cannot be determined until some rehabilitation work is done on the mine workings. The dumps on which radioactive material was found are at the collar of the 660-foot shaft and outside of the 145-level adit. Because the shaft is caved for 175 feet below the surface (Elsing and Faick, 1952), the adit might be the more economical way to re-enter the mine. The 145-level adit is partly caved at the portal and completely caved at 160 feet.

Inasmuch as the uranium-bearing rock was found only locally and on the tops of the dumps, it would seem that the source area or areas in the mine are small but possibly still exposed in a heading. It is suggested that the source areas may be veins or pockets that contain fluorite in a calcite gangue. This mineral association is not typical of the Abe Lincoln vein system so the uranium-bearing areas may well be exposed in workings away from the main veins or they may be veins that intersect the Abe Lincoln vein system.

The Annie Laurie deposit has been examined by Wright (1951), who made a study of the geology and radioactivity, and by Anderson and Kurtz (1955), who did a biogeochemical reconnaissance of the prospect. Both of these papers are believed to present an erroneous interpretation of the local geology. The deposit has been explored by shallow prospect pits and by drilling largely to the west of the prospect pits. The interpretation of the geology as described in this report suggests that vertical drill holes west of the pits would likely diverge from the deposit at depth. The deposit might be more profitably explored from the hillside below pits A through E or from the bottom of the gully shown on figure 11.

Most of the deposits described in this report probably deserve no further examination or exploration based on their value as potentially economic uranium deposits. It is very common for small amounts of uranium minerals to be incorporated in the deposits of various metallogenic provinces. Yet, although these deposits may be exploited for their base or precious metal contents, the uranium contained within them is commonly a local phenomenon and its presence cannot, in many places, be construed as evidence of greater concentrations elsewhere in the deposit.

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